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THESIS

COMPUTER EVALUATION OF THE ON-AND-OFF-DESIGN PERFORMANCE OF AN AXIAL AIR TURBINE

by

Robert Cirone

March 1981

Thesis Advisor R. P. Shreeve

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Computer Evaluation of the On-and-Off-Design Performance of an Axial Air Turbine

by

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Lieutenant, United States Navy
B.S.M.E., University of Notre Dame, 1973

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN MECHANICAL ENGINEERING

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LIST OF SYMBOLS

A	Cross sectional area
a	Blade opening
c	Blade chord
c_p	Specific heat at constant pressure
D	Diameter
E	Kinetic energy
g_c	Universal gravitational constant
H	Total enthalpy
H^{***}	Energy parameter, boundary layer
h	Static enthalpy
h	Blade height
HP	Horsepower
I	Integrand
J	Conversion factor
K_{is}	Head coefficient
L	Distance between stations
M	Mach number
$\dot{m}$	Mass flow rate
m	Exponent used in boundary layer calculations
$\dot{m}_{ref}$	Reference flow rate
N	Rotational speed
P	Pressure (Psia)
R	Gas constant for air

R	Radius
r	Radius
r^*	Theoretical degree of reaction
s	Entropy
s^*	Non-dimensional entropy
T	Temperature (°R)
t	Maximum blade thickness
t_e	Trailing edge thickness
U	Peripheral velocity
u	Velocity within the boundary layer
V	Absolute velocity
W	Relative velocity
X	Non-dimensional radius (r/r_m)
Y	Non-dimensional axial velocity ratio (V_a/V_{am})
y	Pressure loss coefficient

GREEK LETTERS

α	Absolute gas outlet angle
β	Relative gas outlet angle
γ	Specific heat ratio, c_p/c_v
δ	Boundary layer thickness
δ	Referred pressure ratio $(P_{to}/14.7)$
δ^*	Boundary layer displacement thickness
δ^{***}	Boundary layer energy thickness
ξ	Loss coefficient
η	Efficiency

θ	Referred temperature ratio, $\frac{T_{TO}}{518.4}$
κ	Curvature factor
λ	Angle of flow in a meridional plane
§	Area restriction factor
ρ	Density
Φ	Non-dimensional flow function
ω	Angular velocity

SUBSCRIPTS

a	Axial
ACT	Actual or computed value
E	An equivalent thermodynamic quantity
eff	Effective
H	Hub
is	Isentropic
m	Mean streamline value
p	Profile
R	Relative flow value
r	radial
ref	Referred value
req	Required
s	secondary
TH	Theoretical value
TO	Total conditions
u	Tangential
o	Station at the stator inlet

1	Station between the stator and the rotor
2	Station at the rotor outlet

I. INTRODUCTION

A. DESCRIPTION OF THE TRANSONIC COMPRESSOR TEST RIG

The Transonic Compressor Test Rig at the Turbopropulsion Laboratory (TPL) of the Naval Postgraduate School is shown schematically in Fig. 1 and consists of the following major components:

1. Air drive turbine.
2. Air supply system.
3. Associated piping including throttling valves at the turbine and compressor inlets.
4. Test compressor.

The drive turbine is a dual-flow axial air turbine with 50% reaction. The geometry is given in Table 1. The profile shapes of the turbine rotor and of the stator blades are identical and the blades are of constant section along the radius as shown in Fig. 2. The stator has 31 blades while the rotor has 32 (to avoid resonant excitation from wake interference). The two parallel stages of the turbine are designed for the following output and total inlet conditions:

Pressure Ratio: 2.8
Total Inlet Temperature: 640°R
Flow rate: 10.85 LBM/SEC
Horsepower: 485 HP

The compressor presently under test is a transonic single stage, axial flow compressor. It is instrumented for measurements of torque, mass flow rate, stagnation temperatures and pressures, case and hub wall pressures, and for unsteady pressure measurements in the flow field and at the walls.

The Air Supply System incorporates an electric motor-driven multi-stage axial flow compressor manufactured by Allis-Chalmers. It can presently supply up to 12 lbs/sec of air at 3 atmospheres, at temperatures between 560°R and 660°R. The compressor is rated at 1250 HP and has a controlled variable speed drive.

B. STATEMENT OF THE TASK

The Transonic Compressor Test Rig was designed to provide the means for obtaining experimental data in fundamental compressor phenomena. Following the present experiments, an experiment to investigate the onset of supersonic unstalled blade flutter is planned which would involve replacing at least the present compressor rotor by a rotating cascade of flat-plate blades. Such a rotor would not be able to produce the pressure ratios required to pump the required flow rates through the system. Therefore, it has been proposed, that a turbocharger compressor be fitted in series with the rotating cascade to provide the required flow through it. The turbocharger would also be driven using air from the Allis-Charmers air supply system.

In order to evaluate the feasability of the turbocharger installation, it is necessary to determine the mass flow rate required by the drive turbine to drive the test compressor at a given power and speed. The remaining air to drive the turbocharger turbine is then known and the selection of a commercially available turbocharger suitable for this application can be made.

Thus, the performance of the air drive turbine must be known over the complete speed range. Of particular importance, are the required mass flow rates for given values of horsepower. The problem, therefore, is to obtain the turbine performance map for all pressure ratios and speeds.

II. APPROACH

A. BACKGROUND

A search of the most recent literature revealed a number of analytical methods for the calculation of turbine off-design performance. The majority of these used in a finite element approach but little information on the relative success of these methods in practice was available. Two alternate methods, both used at the Turbopropulsion Laboratory, were those of M. H. Vavra and E. Macchi. Each was examined in detail.

The method of Vavra, given in Ref. [1] is a one-dimensional (meanline) approach using mathematical modelling and experimental data to express flow angles and losses. It is primarily a method to design turbine blading but may also be used to predict turbine performance for a given set of gas inlet and operating conditions when the blading geometries are specified. It is assumed that the axial velocity is constant along the blading from hub to tip. Vavra states that this assumtion is reasonable for blading in which the tip-to-hub ratio is equal to or less than 1.15. The ratio is 1.312 and 1.424 for the drive turbine stator and rotor blading respectively. It was thought therefore, that the method of Macchi might yield more accurate predictions.

Macchi's method is given in Ref. [2]. The method, implemented by Macchi in a computer program written for the IBM 360, was an extension of the work done by R. Eckert [Ref. 3] and R. Harrison [Ref. 4]. Eckert wrote a program, following a simplified three-dimensional analysis, which could be used to predict the performance of a single-stage axial flow turbine. Harrison improved the program by modifying the analysis to take into account streamline curvature. Both programs were based on the three-dimensional method developed by Vavra in Ref. [5]. Macchi's principle improvements to the program were to introduce the choice of various methods to calculate gas outlet angles and loss coefficients. Two methods of calculating gas outlet angles are included; those of Ainley and Mathieson [Ref. 6] and Traupel [Ref. 7]. Five methods for calculating the loss coefficients can be selected; those due to Ainley and Mathieson [Ref. 6], Dunham and Came [Ref. 8], Balje [Ref. 9], Lonherr and Carter [Ref. 10] and Traupel [Ref. 7].

Macchi's computer program, as documented in Ref.]2], was selected for performance predictions of the drive turbine. It should be noted that no card deck of the program was available, and no results of using the program were available other than those included in Ref. [2].

B. ANALYSIS

The method requires the following assumptions;

1. There are an infinite number of blades in each blade row so that blades downstream do not affect upstream conditions.

2. The flow is axisymmetric at locations where the equation of motion is solved.

3. The flow is steady and adiabatic. Thus, the total enthalpy through the stator remains constant along a streamline and the relative total enthalpy through the rotor remains constant along a streamline.

4. All equations are solved at between blade row locations. Increases in entropy occur in the blade row upstream of the stations where equations are solved and the entropy change along a streamline between blade rows is zero.

5. The boundary layers on the turbine casing are not accounted for.

The method of solution is as follows:

1. Assume initial radial positions of the streamlines.

2. Obtain the axial velocity distribution by solving the equation of motion at the stator outlet. The velocity distribution into the stator is assumed to be axial, and uniform

3. Obtain stator loss coefficients.

4. Check overall continuity and adjust the inlet Mach number as necessary.

5. Check the between-streamline continuity, and adjust streamline radial positions as necessary.

6. Repeat this process for the rotor.

7. Re-cycle all the above calculations, accounting for streamline curvature, and repeat until convergence is reached.

C. METHOD OF SOLUTION

The computer code written by Macchi was originally run on the IBM 360 computer. The program consisted of a deck of over 2000 program cards plus over 60 data cards. Since the deck could not be located, it was necessary to re-type the program from the listing in Macchi's paper. However, since the IBM 360 computer was soon to be replaced in the period in which the work was to be carried out, an alternate computer was sought.

The HP-1000 series mini-computer located at TPL was selected for two reasons. First, the machine used FORTRAN as did Macchi's program. Secondly, it would be a benefit to TPL to have the program immediately available on the laboratory computer.

The first steps were to analyze Macchi's program, in detail, and then to run it using his example input/output. In analyzing the program it became obvious that the computer program listing given in Ref. 2, was not the one used to obtain the listed output. Numerous discrepancies were found in the listing, some of which would have prevented the program from running; others would have caused incorrect results to be obtained. A listing of these discrepancies is contained in Appendix E. When the program was understood and flow-charted, it was keyed-in at the HP-1000 computer terminal. However, modifications were required to accomodate

the program within the mini-computer disc-based operating system.

D. MODIFICATION TO THE COMPUTER CODE

Since there was no card reader, variable input data such as turbine speed had to be entered using data or specification statements. This contributed in part to the most difficult problem, that of program size. The HP-1000 mini-computer uses a disc with a storage capability of 19.5 mega-bytes. However, the machine memory is only 124 K Bytes, of which only 29 K Bytes is available to a programmer. Also, the available memory is divided up, or partitioned into two 18 K and one 11 K partitions, so that no single program can exceed 18 K. It was estimated that Macchi's program was over 100 K. So it was clear that the program would have to be modified if it were to run on the mini-computer.

The first modification was to remove all subroutines from the program that were not actually used. It will be recalled that Macchi's program contained five methods for calculating loss coefficients and two methods for calculating gas outlet angles. It was decided that only the Traupel method of calculating loss coefficients would be retained. Traupel was selected for two reasons. Firstly, it was the method used by Macchi in his example calculations and therefore the modifed program should still reproduce Macchi's results. Secondly, the method of Traupel is widely respected.

The method of calculating gas outlet angles was totally changed. Neither Ainley and Mathieson [Ref. 6] nor Traupel [Ref. 7] was used. Both methods required prohibitively large sections of computer code. The method selected was that of Vavra [Ref. 1].

Use of Vavra's method greatly simplified the program because this method predicts gas outlet angles independently of the inlet Mach number. Macchi's approach was to use Traupel's method which is dependent on the Mach number of the flow into the blade.

The above simplifications reduced the program size from 2257 lines to less than 1800 lines. However, this was still too large and the program could not be loaded without overflowing the memory.

The solution to the problem was found in program segmentation. In this process, the computer code is divided into a main program and several segments. Each segment is a "piece" of the original program. The segments are individually compiled and loaded. However, the segments are placed into memory only as they are needed to execute the overall program. Thus, a very large program can be made to run in the available 18 K partition. Since the present program was not originally intended for a mini-computer, segmentation was not straight forward. The method finally arrived at is detailed in Appendix C. Basically, the main

program consists of all the subroutines, while the three other segments contain coding which enables program flow to proceed in a logical manner.

Successfully segmented, the program was run using Macchi's input. An output was obtained which agreed almost exactly with Macchi's results. All output quantities were within 1% of Macchi's quantities. The differences were, in all probability, due to the different method of calculating gas outlet angles.

After verifying Macchi's program, the drive turbine geometry was input and the program was run for a given set of operating conditions. The results are discussed in the following section. Note: The "verification" of Macchi's program amounted to verifying that the computer code now loaded into the HP-1000, was indeed Macchi's code. It was not known whether Macchi's output data were a good or bad prediction of performance since they were not compared with test results.

III. RESULTS OF AXIAL TURBINE PREDICTIONS

A. USING BOTH COMPLETE AND MODIFIED PROGRAMS

The drive turbine geometry was input and the following solution flow path was selected:

1. Stator and rotor loss coefficients were functions of pressure ratio.

2. The blockage factor, ξ^*, used in the equation of continuity was equal to the total loss coefficient.

Four operating points were selected to test the validity of the program. Three were off-design points at which measured data were available and the fourth was the design point itself. Table II contains details of the selected test points for Run 1.

The program variables were then changed and the following new solution flow path was selected:

1. Stator and rotor loss coefficients were those calculated by Traupel's method.

2. The blockage factor, ξ^*, was equal to the profile loss coefficient.

After reviewing the results of Runs 1 and 2, a further modification was made to the program. The original program contained a subroutine which checked between-streamline continuity. If the total mass flow rate at the stator and rotor exits was not evenly divided between the five streamlines,

the radial positions of the streamlines were adjusted and all steps were recalculated using the new streamline positions. Hence, for Run 3, a subroutine was removed and the main program was modified so that between-streamline continuity was not examined.

B. COMPARISON WITH MEASURED DATA

The results of Run 1, 2, and 3 are tabulated in Table III. Run 1 showed predictions of mass flow rate which departed about 6% from the measured data. However, the horsepower predictions were off by as much as 16.17%. Furthermore, the computer program was unable to reach a solution for the design point.

Run 2 produced worse results as is evident from the table. Again, the program was unable to converge to a solution at the design point.

Run 3 produced more acceptable data. Additionally, convergence to a solution was noticeably faster and a solution was obtained at the design point. Because of this, the method used in Run 3 was used to map the drive turbine performance. The computer program used to obtain the results of Run 3 is described in detail in Appendix A and is listed in Appendix G. The results of Run 3 are shown plotted in Figures 3 through 8.

To obtain the plots in Figures 3 and 6, a value of the total inlet temperature was approximated by the method of Vavra as contained in Ref. [14]. It was assumed that the static turbine discharge temperature should not be less than

45°F (505°R). This corresponds to the approximate temperature at which condensation of moisture in the air, assuming 100% relative humidity, will occur. The inlet temperature was given by

$$\text{Total Inlet Temperature} = \frac{\text{Static Outlet Temperature}}{1 - \eta_s [1 - (\frac{1}{\delta_T})^{\frac{\gamma - 1}{\gamma}}]}$$

where η_s, the total-static turbine efficiency was assumed to be 81%, and δ_T, was the total to static pressure ratio. The total inlet temperature corresponding to each pressure ratio is given in Table IV.

The computer output corresponding to each point on Figures 3 through 8 is contained in Appendix F. Only one side of the dual flow turbine was analyzed, thus, the resulting printed values of horsepower, referred horsepower, moment, referred moment, flow rate and referred flow rate must be doubled to obtain the actual turbine characteristics which have been plotted in Figures 3 through 8.

IV. DISCUSSION

The agreement of both the predicted flow rate and the horsepower obtained in Run 3 with turbine test data was encouraging. It is to be noted however, that this agreement was obtained using a procedure which was conceptually incorrect. In Runs 1 and 2, between-streamline continuity was checked and the streamlines were adjusted as necessary. In Run 3, between-streamline continuity was not checked, and as a result, the mass flow rate between streamlines was not precisely 25% of the total flow rate. It is noted however, that the deviations were less than 10.0% and while the radial positions of the streamlines varied by 10.%, the differences between predicted and measured output horsepower decreased from 24% to 4.5%. Since the enthalpy change on each streamline was computed using Euler's turbine equation, the total horsepower obtained by integration is sensitive to the streamline radial positions. On the other hand, the calculation of the overall mass flow rate is primarily a function of the blade throat openings and inlet conditions of the flow. Consequently, in relaxing the requirement for between-streamline continuity, the output horsepower was changed significantly, while the overall flow rate was not.

Using this procedure, which preserves overall continuity, a performance map for the turbine was produced (Fig. 3-8) which agreed well with the off-design performance measurements made at lower speeds (Table III). It is noted however, that the inability of the program in its original form to predict the measured turbine performance is not explained, and both the program itself and the data input for the geometry should be closely re-examined.

The difficulty in obtaining convergence to a solution at some operating points above the pressure ratio of 2.0 is likely to be the result of choking occurring on one or more of the streamlines. This was suspected but not fully explored.

Finally, although the program was eventually made to run on the mini-computer, the time required to put the program into its final form was excessive since the original program was not written with segmentation in mind. When the segmented program was completed, only one operating point per run could be obtained. Thus, excessive time was spent compiling and loading the program. The execution time for the program averaged 2 minutes at the lower pressure ratios and up to 30 minutes at the higher ones. This would be unacceptable if many points were to be examined.

V. CONCLUSIONS

The program for calculating the performance of a single stage axial turbine reported by Macchi was revised, corrected and segmented and made to run on the Laboratory mini-computer. When applied to the geometry of the air-drive turbine of the compressor test rig, selecting specific options for the representation of loss coefficients, the revised program failed to converge when design-point test conditions where input. Also, the computed horsepower was in error by as much as 24% when the program predictions were compared with specific test data obtained from the rig at off-design (lower speed) conditions. The revised program did however closely reproduce the results given by Macchi in his original report for a specific turbine geometry.

When the requirement that the computed stream surfaces be such that they divided the flow exactly into equal 25% increments was removed, the program converged satisfactorily for design point conditions and gave agreement with test data to within 5% in flow rate and horesepower at off-design conditions.

The complete performance map for the air drive turbine was obtained with the program following this revision. Based on the favorable comparison with data so far obtained, the map is likely to describe the performance to better than a 10% uncertainty. This is considered to be satisfactory for

sizing the turbocharger for the proposed compressor rig modification.

The following recommendations are made concerning further application or development of the computer program:

1. The failure of the program to converge before the final revision was made should be analysed closely, and the final revision removed if possible.
2. The geometrical input for the air drive turbine (which was taken from drawings) should be reexamined and the physical dimensions of the blade rows themselves should be measured.
3. Consideration should be given to putting the corrected original version of the program onto the IBM 370 computer so that, when successfully operating, a turbine map can be calculated with a single load.

TABLE I

TURBINE GEOMETRY

(see Figure 2; Dimensions in inches)

STATOR:

Hub Radius	2.764
Mean Radius	3.196
Tip Radius	3.627
Blade Chord	1.003
Blade Suction Side Radius of Curvature	2.8065
Maximum Blade Thickness	.2252
T.E. Projected Thickness	.03
T.E. Normal Thickness	.0186

ROTOR:

Hub Radius	2.693
Mean Radius	3.265
Tip Radius	3.837
Blade Chord	1.003
Blade Suction Side Radius of Curvature	2.8065
Maximum Blade Thickness	.2252
T.E. Projected Thickness	.03
T.E. Normal Thickness	.0186
Tip Clearance	.01(estimated)

TABLE II

MEASURED/DESIGN DATA USED TO VERIFY THE PROGRAM

POINT	RPM	T_{IN} (R)	T_{OUT} (R)	P_{TO} (PSI)	P.R.	$M(\frac{LBM}{SEC})$	H.P.
1	18310	579.2	550.8	23.56	1.602	5.542	110.1
2	15200	557.4	517.8	20.43	1.390	4.698	63.27
3	21300	578.9	506.8	27.13	1.846	7.033	172.0
4*	30500	640.0	---	41.16	2.8	10.85	485

*Design Point

TABLE III

COMPARISON OF PREDICTED TURBINE PERFORMANCE VS MEASURED PERFORMANCE

RUN I

	FLOWRATE			HORSEPOWER		
POINT	PREDICT.	MEAS.	%DIFF.	PREDICT.	MEAS	%DIFF.
1	5.88	5.542	6.09	99.5	110.1	9.63
2	4.74	4.698	0.89	52.5	63.27	16.17
3	7.04	7.033	0.009	163.64	172.0	4.86
4	N.C.	10.85	---	N.C.	485	---
			RUN 2			
1	6.06	5.542	9.35	90.92	110.1	17.4
2	4.90	4.698	4.29	49.76	63.27	21.35
3	7.30	7.033	3.80	130.76	172.0	23.97
4	N.C.	10.85	---	N.C.	485	---
			RUN 3			
1	5.82	5.542	5.01	113.12	110.1	2.74
2	4.66	4.698	0.81	61.96	63.27	2.09
3	7.04	7.033	0.10	179.68	172.0	4.47
4	10.40	10.85	4.15	444.18	485	8.42

NC: Computer program would not converge to a solution after a large number of iterations.

TABLE IV

VALUES OF ASSUMED TOTAL INLET TEMPERATURE FOR EACH PRESSURE RATIO GIVEN IN FIGS. 3, 5, 6, AND 7

PRESSURE RATIO	TOTAL INLET TEMPERATURE (°R)
1.4	545.5
1.6	562.6
1.8	577.3
2.0	591.0
2.2	603.6
2.4	615.3
2.6	626.1
2.8	636.6

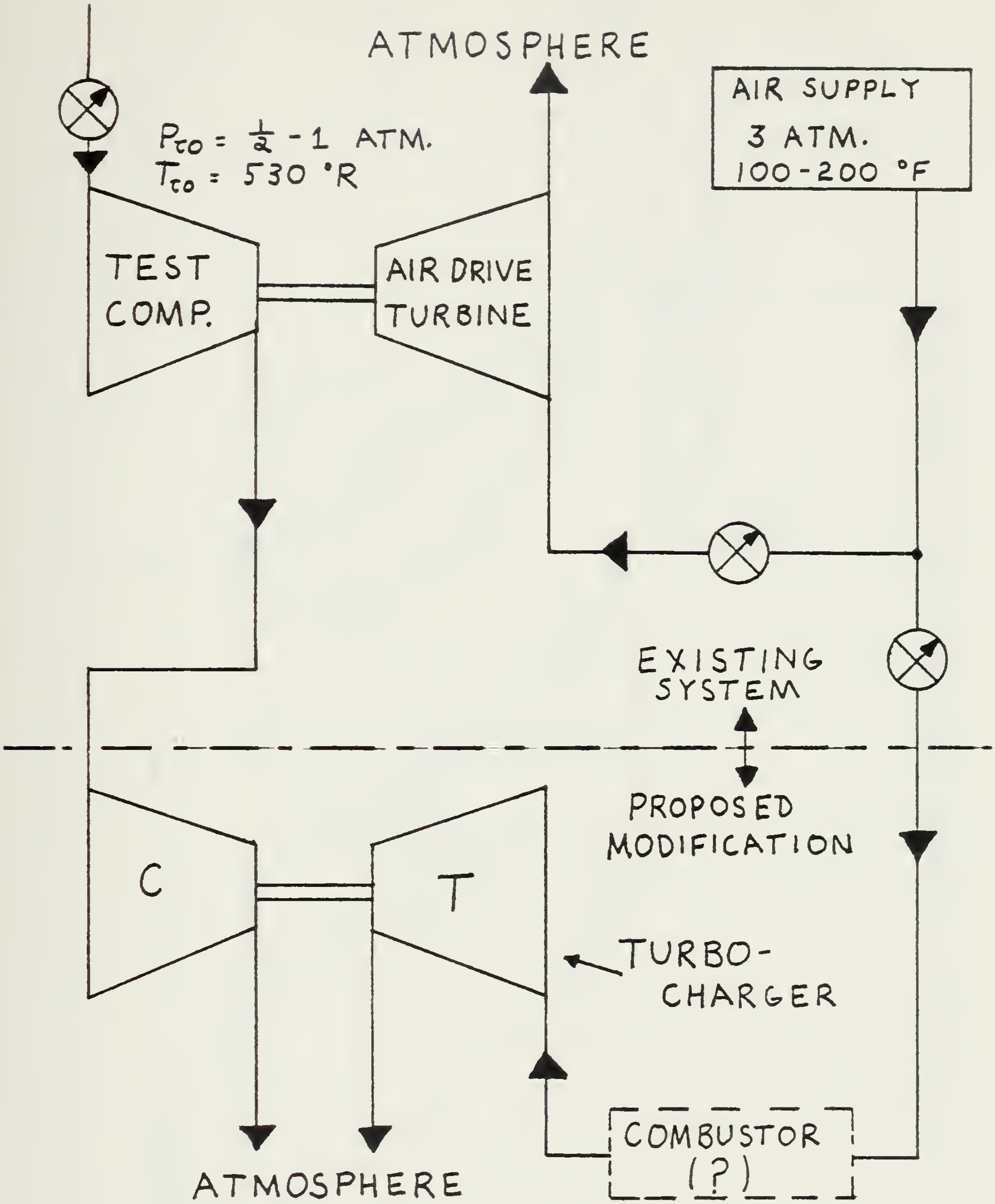


FIGURE 1: SCHEMATIC OF THE COMPRESSOR TEST RIG, WITH PROPOSED MODIFICATIONS

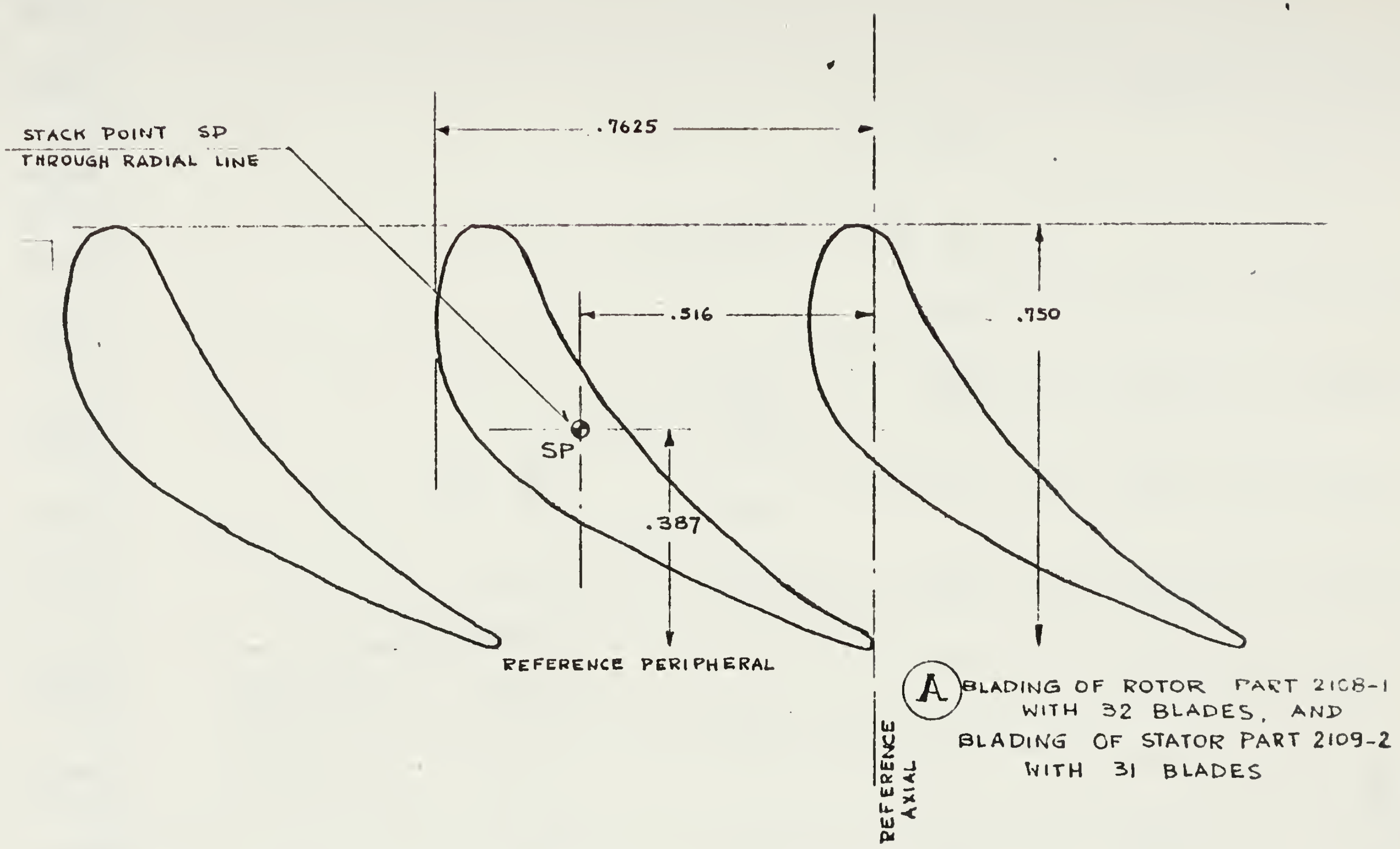


FIGURE 2: TURBINE ROTOR AND STATOR BLADE SHAPES

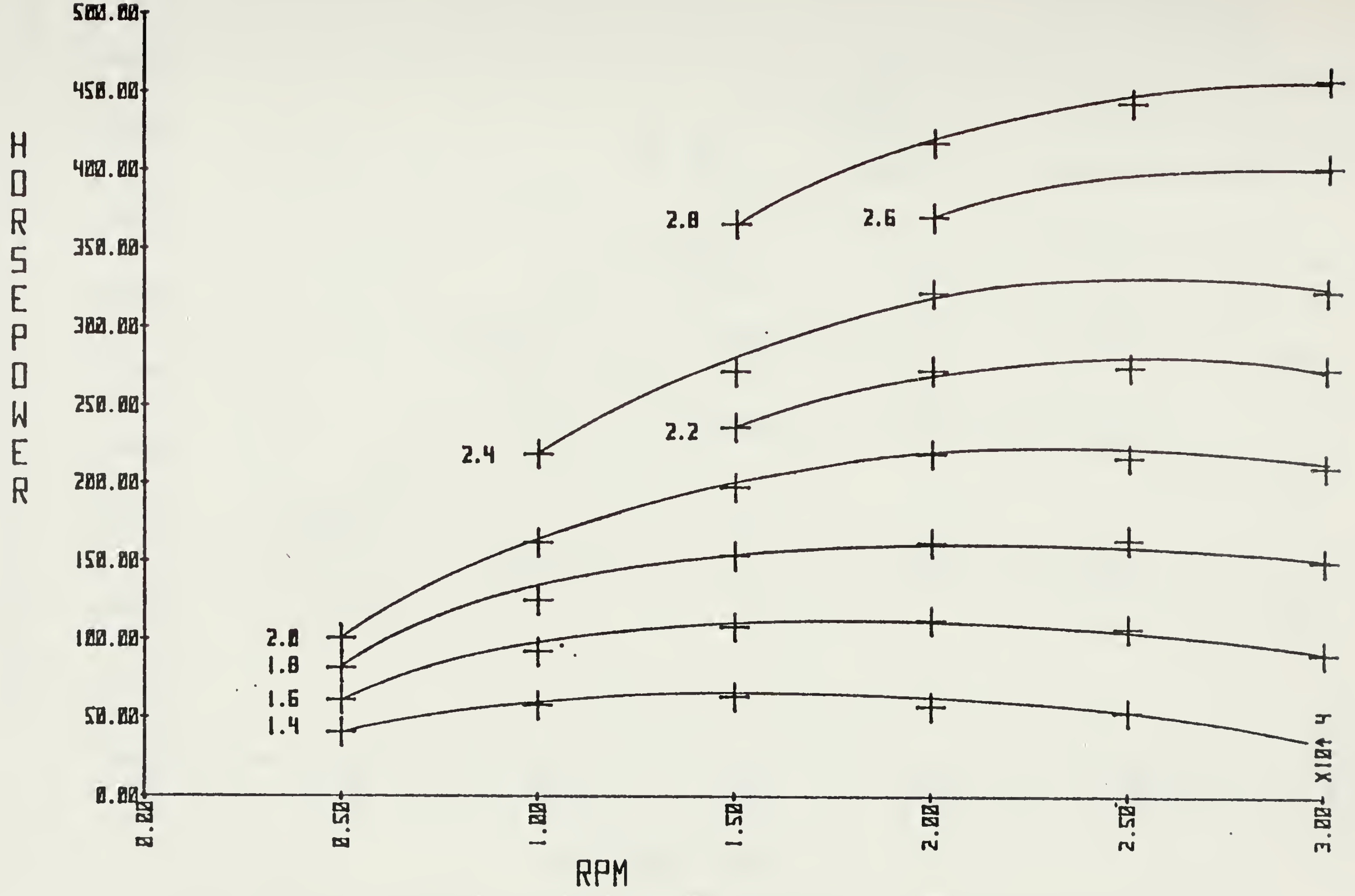


FIGURE 3: PREDICTED HORSEPOWER VS RPM AS A FUNCTION OF PRESSURE RATIO, AT TEMPERATURES TO AVOID CONDENSATION

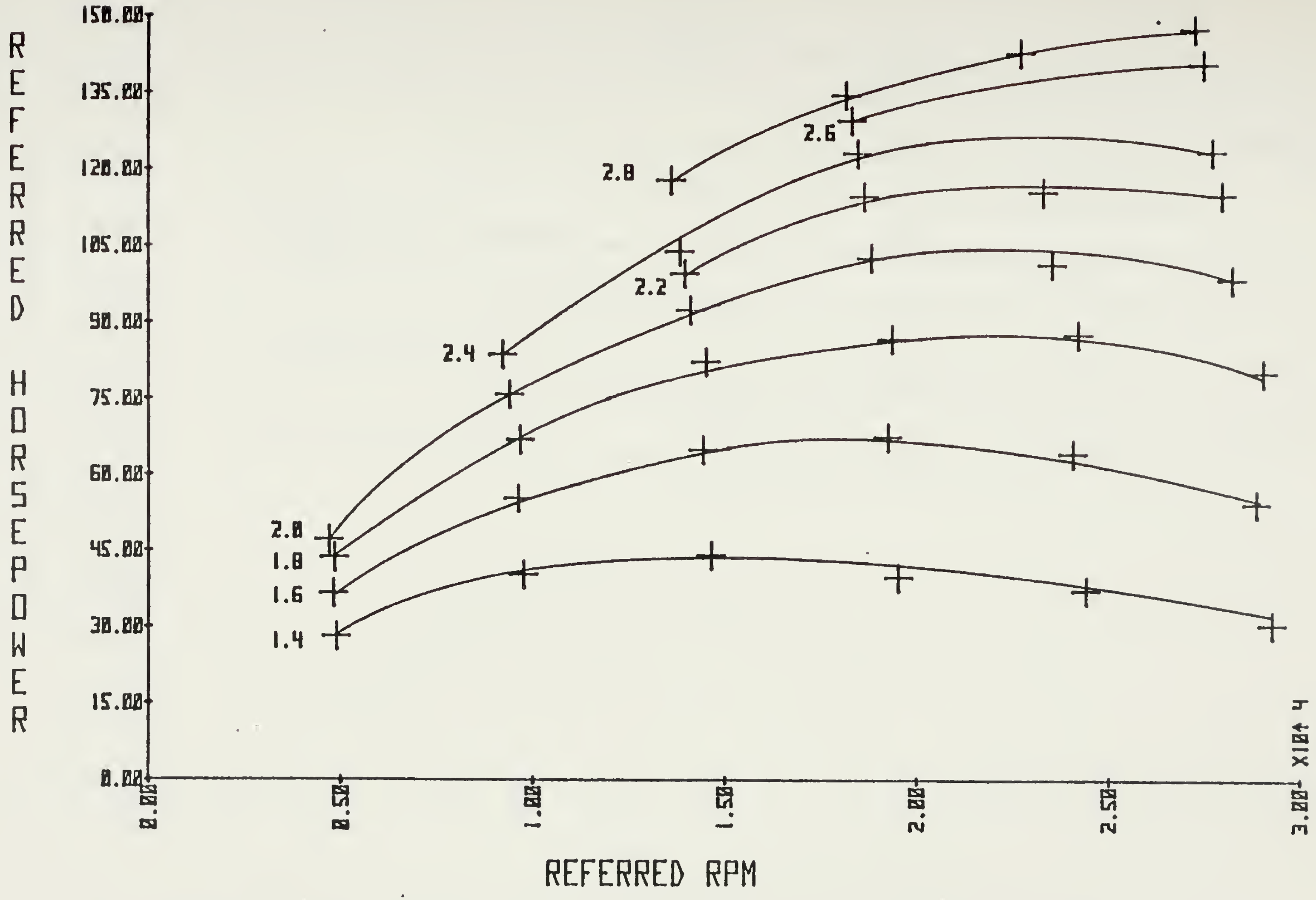


FIGURE 4: PREDICTED REFERRED HORSEPOWER VS REFERRED RPM AS A FUNCTION OF PRESSURE RATIO

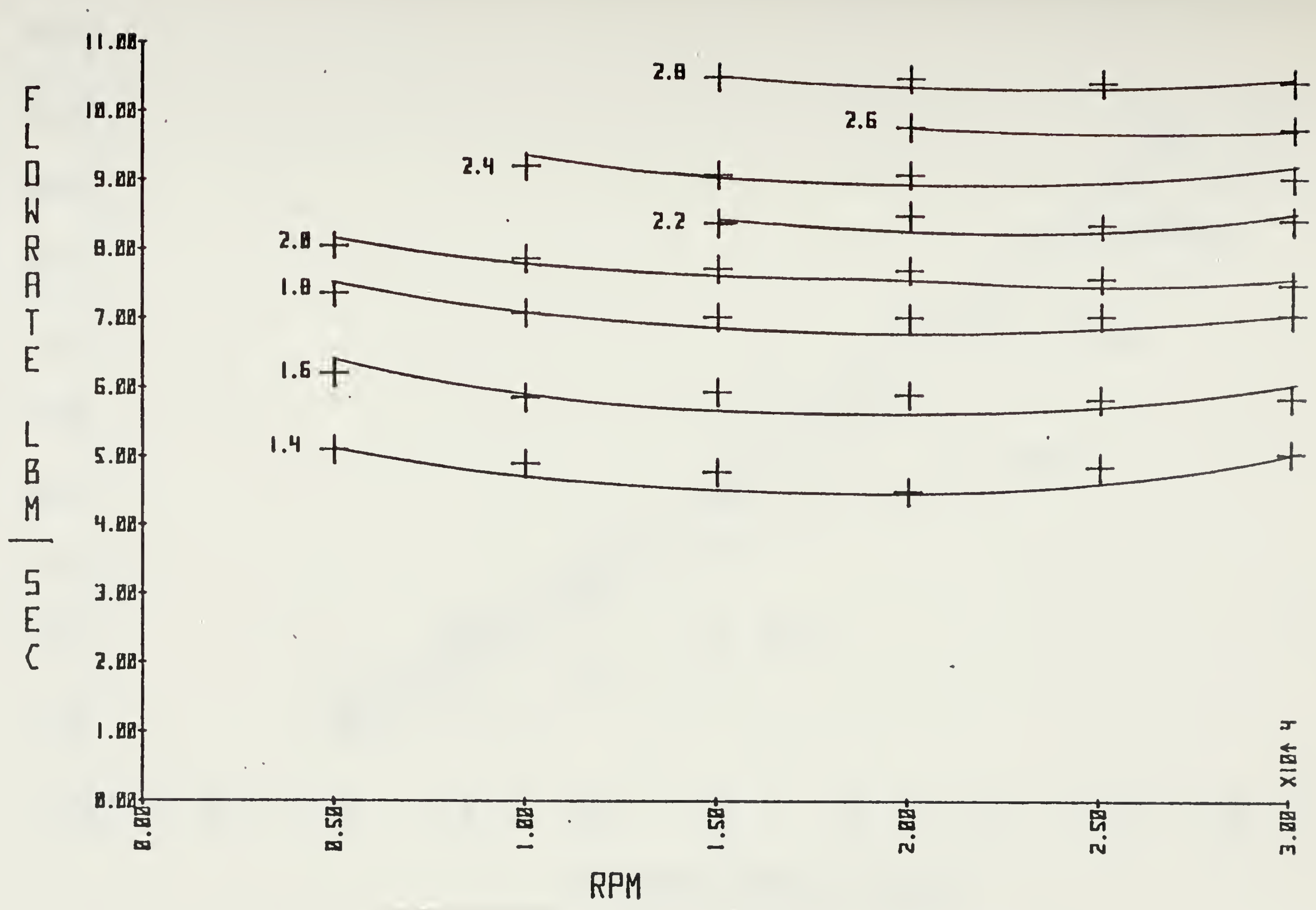


FIGURE 5: PREDICTED FLOWRATE VS RPM AS A FUNCTION OF PRESSURE RATIO AT TEMPERATURES TO AVOID CONDENSATION.

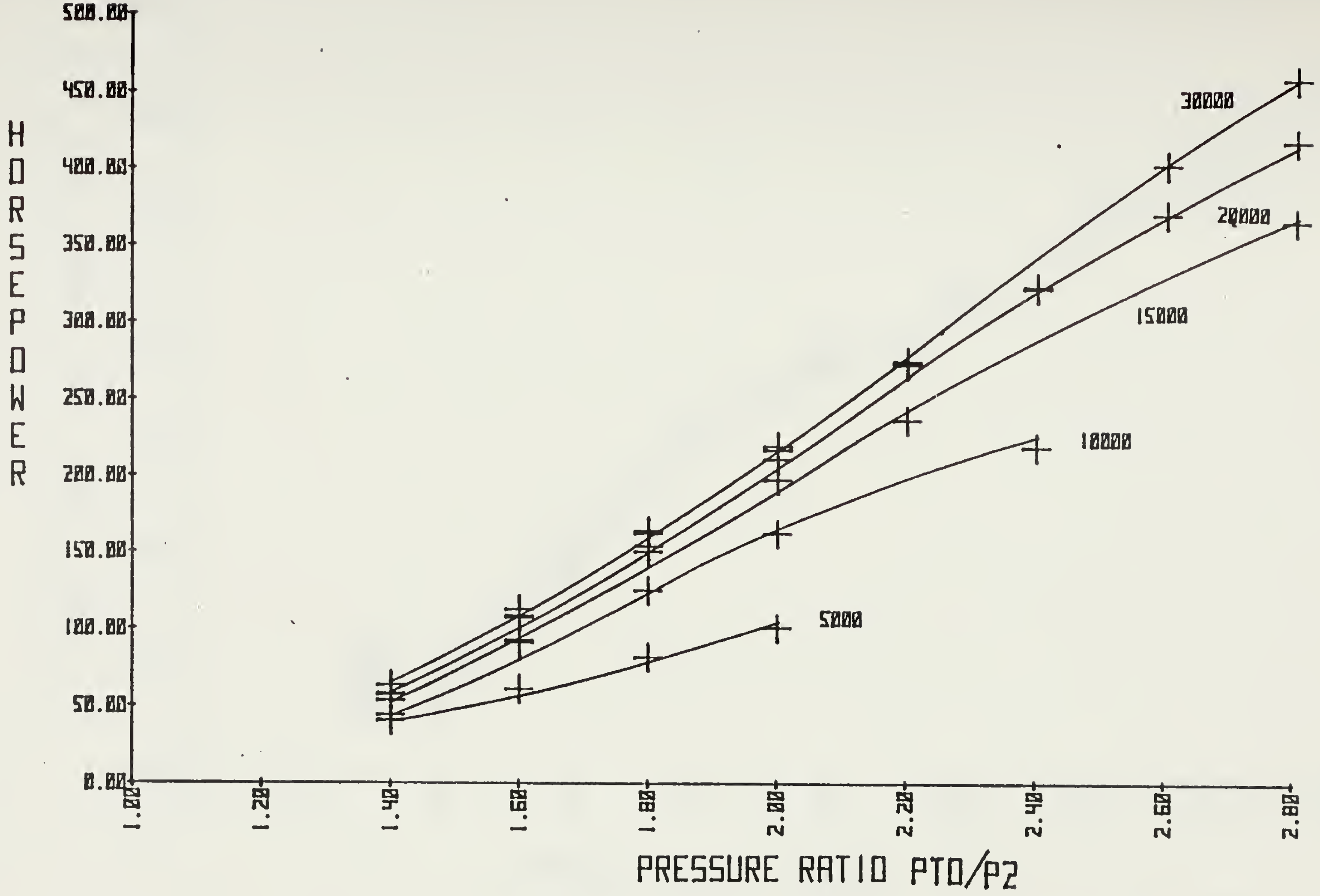


FIGURE 6: PREDICTED HORSEPOWER VS PRESSURE RATIO AS A FUNCTION OF RPM, AT TEMPERATURES TO AVOID CONDENSATION

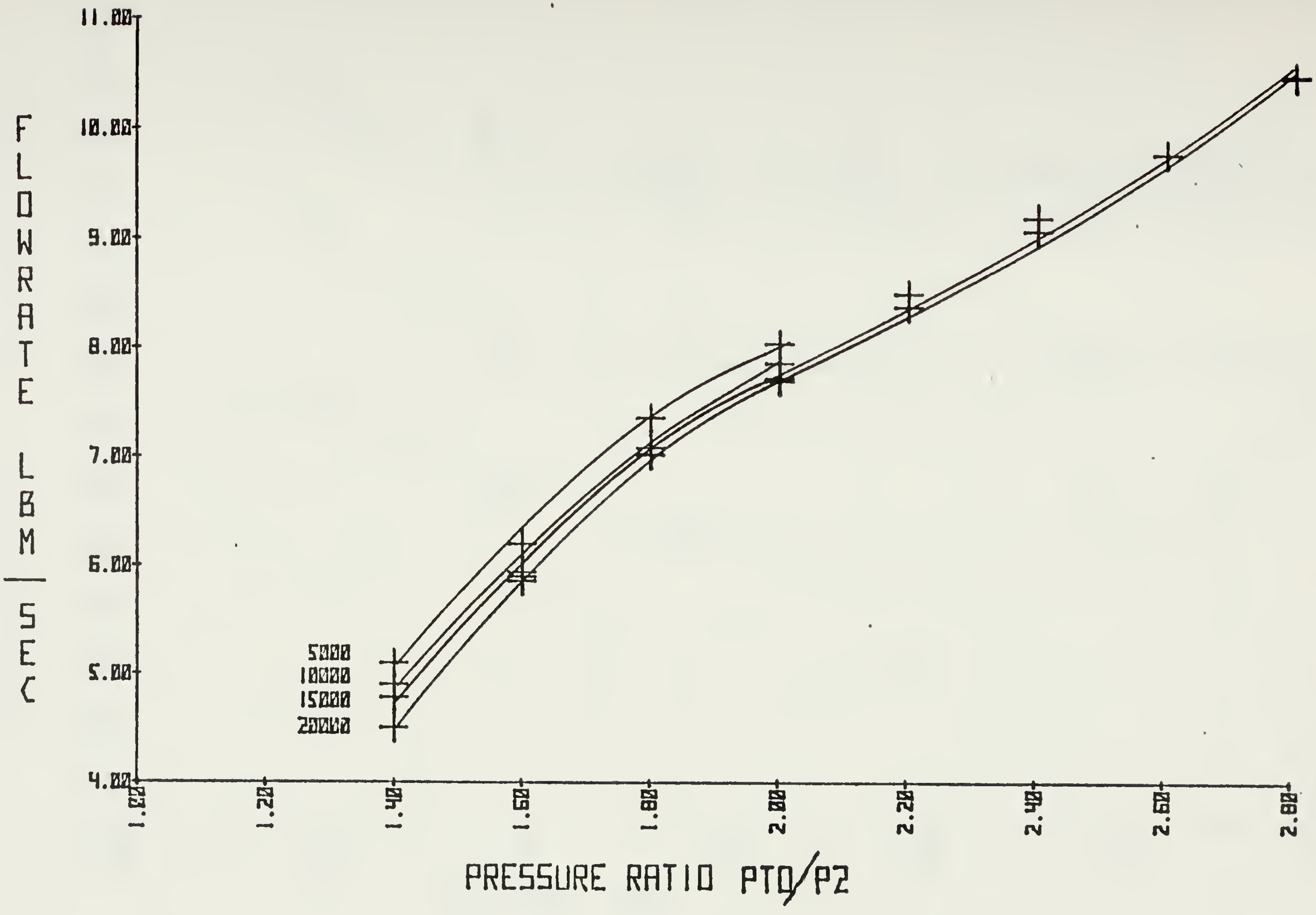


FIGURE 7: PREDICTED FLOW RATE VS PRESSURE RATIO AS A FUNCTION OF RPM AT TEMPERATURES TO AVOID CONDENSATION.

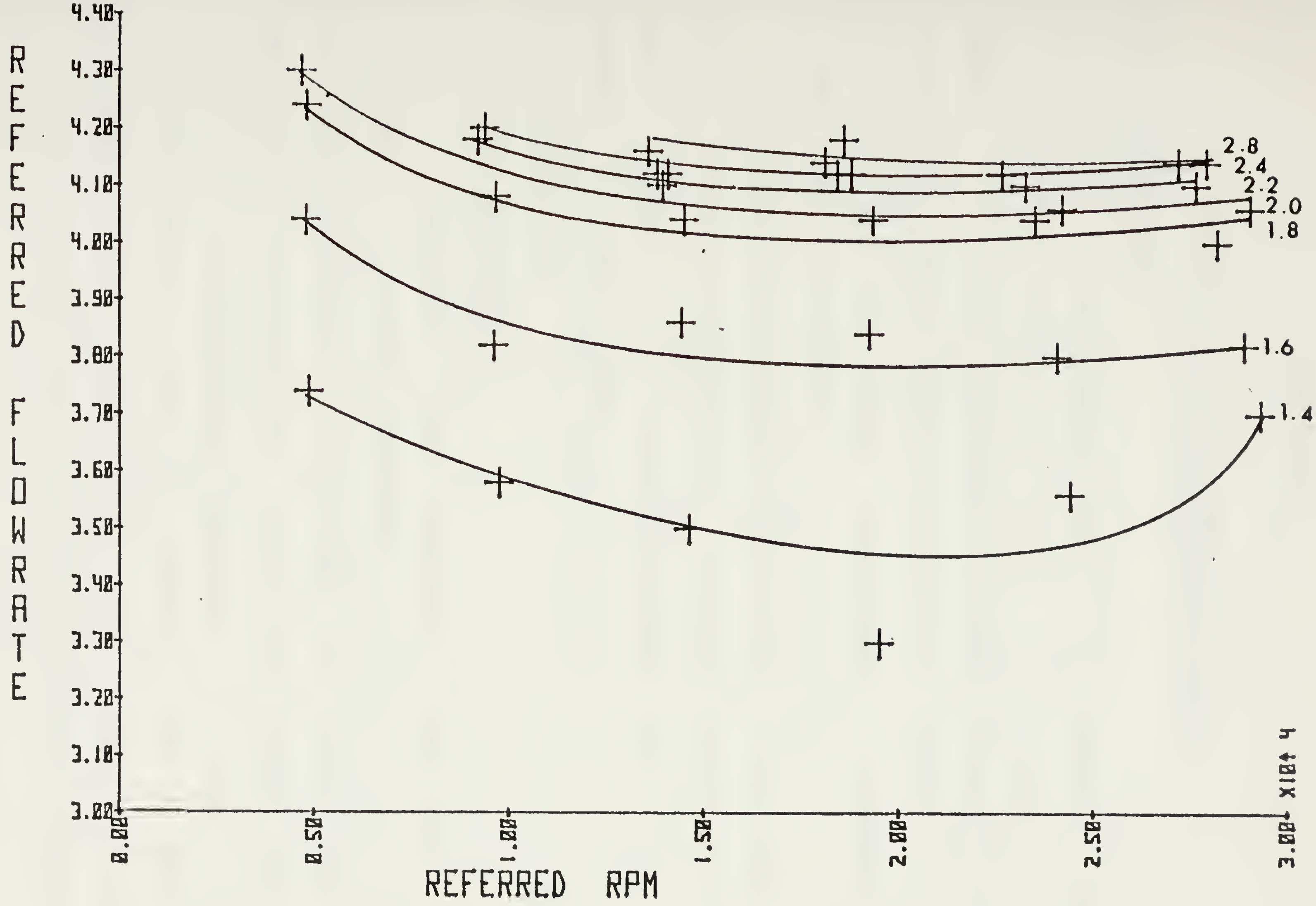


FIGURE 8: PREDICTED REFERRED FLOWRATE VS REFERRED RPM AS A FUNCTION OF PRESSURE RATIO

APPENDIX: A

DESCRIPTION OF THE COMPUTER PROGRAM

A-1. INTRODUCTION

To enable the program to run on the laboratory computer, the program was divided into 4 parts; a main program and 3 segments. A detailed discussion of program segmentation on the HP-1000 computer series is contained in Appendix C. In the description which follows, the program is treated as if it were one large program with many subroutines.

The description follows the individual steps from start to finish in the analysis. A program flowchart is given in Figure A-1 and the FORTRAN symbols used in the program are listed in Tables A-I to A-IX.

A-2. DESCRIPTION

A-2.1 Input Data

There are 4 basic categories of input data; turbine geometry, operating conditions, special data and program control parameters. Since there was no card reader input device on the computer, all data were entered using either data or specification statements. Explanations of the turbine geometry, operating conditions, special data and program control parameters are found in Table A-I through A-V. The nomenclature for the blading is given in Figure A-2.

A-2.2 Initial Geometric Calculations

The first calculation performed is to establish the 5 streamline locations at the stator inlet (station 0). The streamlines are initially positioned such that there are equal areas (25% of the total flow area) between them. Next, blade heights of the stator and rotor are calculated using the hub and tip radii of each blade. Blade spacings for the stator and rotor are computed at 3 streamlines; hub, mean and tip. The blade spacing on the mean streamline for the stator is given by

$$S = \frac{2\pi}{Z_s} Rm \tag{A-1}$$

where S = Blade spacing

Z_s = Number of stator blades

Rm = Mean stator radius

A-2.3 Calculation of Gas Outlet Angles

Subroutine VAVRA calculates gas outlet angles for both stator and rotor. The method is that of M.H. Vavra [Ref. 1]. The equation programmed in the subroutine is

$$\alpha = \cos^{-1}\left[\frac{a}{S} + 4\,\frac{t_e}{S}\left(1 - \frac{\cos^{-1}\left(\frac{a}{s}\right)}{90}\right)\right] \tag{A-2}$$

where α = Gas outlet angle

a = Throat opening

S = Blade spacing

t_e = Projected trailing edge thickness

This method is much simpler than that used by Macchi since

there is no variation in outlet angle with Mach number (for sub-sonic conditions). Therefore, once calculated, the stator and rotor exit angles remain unchanged. Subroutine VAVRA computes exit angles for the hub, mean and tip streamlines. The outlet angles at streamlines two and four are computed later in the subroutines STATR and ROTO2.

Before printing the input data, the program calculates the mean throat opening for the stator and for the rotor. The ten equally spaced radii and corresponding throat openings (part of the input geometry) are fitted with a fourth order Chebyschev polynomial. A throat opening corresponding to the mean radius is thus obtained. In the present application of the program to the drive turbine, the mean throat opening was obtained from the design drawing of the blading shown in Figure 2. It was assumed that the throat opening varied linearly with radial position and hence the throat openings at other radii could be calculated. The resulting throat openings are shown in the computer output under the heading of "Input Prints". The design values of the stator and rotor throat areas were obtained from the original design notes of M.H. Vavra.

A-2.4 Calculation of the Flow Rate

Subroutine CHAN is called to calculate the mass flow rate entering the stator. The equations used are as follows:

$$T = \frac{T_{TO}}{1 + \frac{\gamma - 1}{2} M_0^2} \qquad \text{(A-3)}$$

$$V = \sqrt{g_c \gamma R T} \qquad \text{(A-4)}$$

$$P = \frac{P_{TO}}{1 + \frac{\gamma - 1}{2} M_0^2} \qquad \text{(A-5)}$$

$$\rho = P/RT \qquad \text{(A-6)}$$

$$A = \pi \left[R^2_{TIP} - R^2_{HUB} \right] \qquad \text{(A-7)}$$

$$\dot{m} = \rho A V \qquad \text{(A-8)}$$

$$\dot{m}_{REF} = \frac{\dot{m}}{P_{TO}} \sqrt{\frac{R T_{TO}}{g_c}} \qquad \text{(A-9)}$$

$\dot{m}_{ref}$ is the reference (dimensionless) flowrate and is used to check overall continuity later in the program.

A-2.5 Solution of the Equation of Motion for the Stator

Subroutine STATR is called to solve the equation of motion for the stator outlet conditions. The equation of motion which is programmed is as follows:

$$\frac{d(\ln Y_1^2)}{dX_1} = -\cos^2\alpha_1 \left[-\left(K\, 2 r_m \frac{\delta R}{L^2}\right) - \left(\frac{4L^2 + (\delta r)^2}{4L^2} \right) \cdot \frac{dS_1^*}{dX_1} \right] - 2 \tan\alpha \frac{d\alpha_1}{dX_1} - \frac{2}{X_1} \sin^2\alpha_1 + \frac{C_1 \cos^2\alpha_1}{Y_1^2 Va_{1m}^2} \frac{dH}{dX_1} - \left[\frac{C_1 H \cos^2\alpha_1}{Y_1 Va_{1m}^2} - \sin^2\alpha_1 \right] \frac{ds_1^*}{dX_1} \qquad \text{(A-10)}$$

where $C_1 = 2 g_c J$ (a constant to convert H, the enthalpy from $\frac{\text{BTU}}{\text{LBM}}$ TO $\frac{\text{FT}^2}{\text{sec}}$)

$$Y_1 = \frac{V_a(I)}{V_a(3)} = \frac{\text{Axial velocity at a streamline}}{\text{Axial velocity at mean streamline}}$$

$$X_1 = \frac{R(I)}{R_m} = \frac{\text{Streamline radius}}{\text{Mean streamline radius}}$$

$$\frac{ds^*}{dX_1} = \frac{d}{dX}\left[\ln\left[\frac{1 - \frac{Y_1^2 V_{a_m}^2}{C_1 H \cos^2\alpha_1}}{1 - \frac{Y_1^2 V_{a_m}^2}{C_1 H \cos^2\alpha (1-\xi)}}\right]\right]$$

ξ = Stator loss coefficient (which is initially assigned an estimated value)

The derivation of this form of the equation of motion is given in Appendix B. However, at this stage of the analysis, the streamline curvature is assumed to be zero. Therefore, the equation of motion becomes:

$$\frac{d(\ln Y_1^2)}{dX_1} = -2\,\mathrm{TAN}\,\alpha_1 \frac{d\alpha_1}{dX_1} - \frac{2}{X_1}\,\mathrm{SIN}^2\alpha_1 + \frac{C_1 \cos^2\alpha_1}{Y_1^2 V_{a_{1m}}^2} \cdot \frac{dH}{dX_1} + \left[1 - \frac{C_1 H \cos^2\alpha_1}{Y_1^2 V_{a_{1m}}^2}\right]\frac{ds^*}{dX_1} \tag{A-11}$$

The equation of motion is solved when the value of Y_1 at each streamline satisfies the equation. The solution is to first put the equation in the form:

$$\frac{d(\ln Y_1^2)}{dX_1} = I(X) \tag{A-12}$$

where I(X) consists of the right hand side of equation (A-11). Integrating equation (A-12) yields;

$$\ln Y_1^2 = \int_{x0}^{x} I(x)\,dX_1 + \ln c^2 \qquad \text{(A-13)}$$

where $\ln c^2$ is the constant of integration when $x = 1$ and $Y_1 = 1$. With these boundary conditions Eq. (A-13) gives

$$\ln c^2 = -\int_{x0}^{1} I(x)\,dX_1 \qquad \text{(A-14)}$$

using Eq. (A-14) in Eq. (A-13),

$$\ln Y_1^2 = \int_{X_0}^{X_1} I(x)\,dX_1 - \int_{x0}^{1} I(x)\,dX_1 \qquad \text{(A-15)}$$

which becomes

$$\ln Y_1^2 = \int_{1}^{X_1} I(x]\,dX_1 \qquad \text{(A-16)}$$

Taking the inverse natural log and the square root of both sides

$$Y_1 = e^{\frac{1}{2}\int_{1}^{X} I(x)\,dX_1} \qquad \text{(A-17)}$$

Equation (A-17) is the form of the equation of motion solved in subroutine STATR. Solution of the equation gives five values of Y_1 and thus the value of the axial velocity at each of the five streamlines. Initially, the value of Y_1 is taken to be 1 and the value of $\frac{ds^*}{dx_1}$ is taken to be zero. In succeeding iterations, the calculated value of Y_1 is used to obtain a new value of $\frac{ds^*}{dx_1}$, and so on.

After calculating five values of Y_1, the stator exit conditions are calculated at each streamline from the geometry of the velocity diagram. The convention for positive

and negative angles and velocities is defined in Figure A-3. The required relations are the following:

$$V_{a_1} = V_{a_1}(3) \cdot Y_1 \tag{A-18}$$

$$V_{u_1} = V_{a_1} \cdot \mathrm{TAN}\,\alpha_1 \tag{A-19}$$

$$V_1 = V_{a_1} / \cos\alpha_1 \tag{A-20}$$

$$V_{R_1} = -V_{a_1}\left[\Delta R / 2L\right] \tag{A-21}$$

where L is the axial distance between stations and ΔR is the change in radial position of the streamline. V_{r_1}, the radial component of velocity, is taken to be zero at this stage in the calculation.

$$V_1 = \sqrt{V_1^2 + V_R^2} \tag{A-22}$$

$$T_1 = T_{TO} - \frac{V_1^2}{2 g_c J C_p} \tag{A-23}$$

$$T_{1,s} = T_{TO} - \left[\frac{T_{TO} - T_1}{1 - \xi_s}\right] \tag{A-24}$$

$$P.R. = P_1 / P_{TO} \tag{A-25}$$

$$P_1 = P_{TO}\left[\frac{T_{1,s}}{T_{TO}}\right]^{\frac{\gamma}{\gamma-1}} \tag{A-26}$$

$$M_1 = V_1 / \sqrt{\gamma g_c R T} \tag{A-27}$$

After the above quantities have been calculated at each streamline, subroutine STATR returns to the main program.

A-2.6 Calculation of the Stator Loss Coefficients

The calculation of the stator loss coefficients at each streamline is accomplished by subroutine ALOS1.

The method of solution to obtain these loss coefficients is that formulated by Traupel [Ref. 7]. In Traupel's method, the value of the total loss coefficient is given by

$$\xi_{\text{total}} = \xi_{\text{profile}} + \xi_{\text{wall}} + \xi_{\text{remaining}} \qquad \text{(A-28)}$$

The calculation of ξ_{total} requires 9 subroutines. Figure A-4 describes the connection between the subroutines and subroutine ALOS1.

The first step is to obtain the value of the total profile loss coefficient, ξ_p. ξ_p is defined by Traupel to be

$$\xi_p = \xi_{po} \chi_m \chi_\delta + \xi_m + \xi_f \qquad \text{(A-29)}$$

where ξ_{po} = initial value of the profile loss coefficient

x_m = mach number correction factor

x_δ = trailing edge thickness correction factor

ξ_m = loss coefficient due to mixing losses and separation losses

ξ_f = loss coefficient due to fan losses

The total profile loss coefficient is calculated in the following manner. First, data for initial profile loss (ξ_{po}) as a function of gas outlet angle (α_1) for various values of gas inlet angle (α_0) is read from an array (Fig. A-5).

This is done by subroutine TRAU1 and functions XPO and YC. The values of ξ_{po} are contained in two arrays XPO1 (5, 8) and XPO2 (6, 8). This is because the data shown plotted in Fig. A-5 has been divided into two sets. One set is for values of α_1 between 40° and 80°. The other is for values of α_1 between 80° and 170°. The FORTRAN symbols for the two ranges of values of α_1 are ALFO1(I) and ALFO2(I) respectively. The FORTRAN symbol for the gas inlet angle is ALF1 (J) once the data pints selected from the plot are entered, fifth and sixth degree polynomials respectively are fitted through the data points. The value of ξ_{po} can then be determined for given values of α_1 and α_0.

The mach number correction, X_m is obtained from Fig. A-5. Subroutine CSIM calculates the value of X_m using straight line approximations of the plot.

Subroutine CID calculates the remaining terms in the expression for ξ_p. These are X_s, ξ_m, ξ_f. They are obtained from the data in Fig. A-6 using the linear interpolation. The abscissa of the curves for X_s and ξ_m is either f or 1-f where f is defined as

$$f = 1 - \frac{\delta}{t \sin\alpha_1} \qquad \text{(A-30)}$$

where δ = normal trailing edge thickness.

t = blade spacing.

α_1 = gas outlet angle.

The loss coefficient due to wall friction, ξ_w, is calculated using

$$\xi_W \cong \xi_{PO} \cdot \chi_P \frac{t \sin\alpha}{\ell} \qquad \text{(A-31)}$$

where t - blade maximum thickness

ℓ = blade height

This equation is programmed in subroutine CSIW.

The value of ξ_R is obtained using subroutine CSIR. ξ_R is defined by Traupel to be an all-inclusive loss coefficient which accounts for any remaining losses not previously defined. It is written as

$$\xi_R = \chi_L \xi_{RO} \qquad \text{(A-32)}$$

ξ_{RO} is an initial value of ξ_R which depends on the value of ϕ, where ϕ is given by

$$\phi = \frac{V_1 \sin\alpha_1}{U} \qquad \text{(A-33)}$$

in which v_1 = true velocity of gas

v = blade speed

A plot of ξ_{RO} vs ϕ is shown in Fig. A-7. The correction X_L is a function of s/ℓ where

s = chord length

ℓ = blade height

and is obtained using the data in the lower half of Fig. A-7.

The total stator loss coefficient is computed for 3 streamlines; those at the hub, mean and tip.

The loss coefficients at streamlines 2 and 4 are obtained by linear interpolation.

A refinement to the stator loss coefficient may be applied depending on the input value of one program control parameter. The following 3 variations of ξ_s are available:

$$\xi_s = \frac{\left[\dfrac{1+\xi_o}{1+\xi_o \frac{P}{P_{TO}}}\right]^{\frac{\gamma-1}{\gamma}} - 1}{\left[\dfrac{1}{\frac{P}{P_{TO}}}\right]^{\frac{\gamma-1}{\gamma}} - 1} \qquad \text{(A-34)}$$

$$\xi_s = \xi_o \qquad \text{(A-35)}$$

and

$$\xi_s = \frac{\left[\dfrac{1+\xi_o}{1+\xi_o \beta^*}\right]^{\frac{\gamma-1}{\gamma}} - 1}{\left[\dfrac{1}{\beta^*}\right]^{\frac{\gamma-1}{\gamma}} - 1} \qquad \text{(A-36)}$$

where ξ_0 = loss coefficient calculated using the method of Traupel

$$\beta^* = \left[1 + \frac{\gamma-1}{2}(.8)^2\right]^{\frac{\gamma-1}{\gamma}} \qquad \text{(A-37)}$$

The values of the program control paramenter required to select between options are given in Table A-V.

Before returning to the main program, subroutine ALOS1 calculates a value of ξ^* which is a blockage factor to be used in the equation of continuity. There are three ways to define ξ^*; they are as follows:

$$\xi^* = \xi_o \tag{A-38}$$

$$\xi^* = \frac{1}{2}\xi_o \tag{A-39}$$

$$\xi^* = \xi_P \tag{A-40}$$

A-2.7 Solution of the Continuity Equation After Returning to the Main Program

The overall continuity at the stator exit is checked. Subroutine FLOWR performs this task. The flow chart for FLOWR is given in Fig. A-8. In FLOWR the mass flow rate required by continuity is checked against the calculated mass flow rate. If the calculated flow rate does not agree with that required by continuity, adjustments are made to the axial velocity and/or the inlet Mach number, as will be explained.

The mass flow required by continuity is

$$\dot{m}_{REQD} = \frac{\dot{m}_{REF}}{Z_S \cdot A_m R_m} \tag{A-41}$$

where $\dot{m}_{REF}$ = reference mass flow rate as computed in subroutine CHAN

Z_s = # of stator blades

A_m = mean stator throat opening

R_m = mean stator radius

The mass flow rate at each streamline computed in this subroutine is

$$\dot{m}_{ACT} = \left[\frac{P_{TE}}{P_{TO}}\right] \sqrt{\frac{T_{TE}}{T_{TO}}} \left[\frac{A(I)}{A(3)}\right] Z \, \Phi \qquad \text{(A-42)}$$

where Z is an area reduction coefficient defined by

$$Z = \frac{H^{***} - 1}{H^{***} - 1 + \xi^{*}} \qquad \text{(A-43)}$$

Z gives the percentage of flow area between the blades overwhich it is permissable to assume a uniform velocity. The boundary layer on both sides of the flow limits the available flow area and the backage facotr, Z. accounts for this. Equation A-43, Z is seen to be a function of the energy parameter H*** and ξ*. ξ* is the value of the loss coefficient returned from subroutine ALOS1. The energy parameter is defined as

$$H^{***} = \frac{\delta 3}{\delta 1} = \frac{\text{Energy thickness}}{\text{Displacement thickness}} \quad \text{(A-44)}$$

H*** can be written as

$$H^{***} = \frac{\left[\frac{1}{X_E-1} + \frac{1}{3m+1} + \frac{X_E}{5m+1} + \frac{X_E^2}{7m+1} + \frac{X_E^3}{9m+1} + \frac{X_E^4}{11m+1}\right]}{\left[\frac{1}{X_E-1} + \frac{1}{m+1} + \frac{X_E}{3m+1} + \frac{X_E^2}{5m+1} + \frac{X_E^3}{7m+1} + \frac{X_E^4}{9m+1}\right]} \quad \text{(A-45)}$$

where:

$m = .15$

$X_E = 1-\left(\frac{P}{P_{TO}}\right)^{\frac{\gamma-1}{\gamma}}$ for unchoked flow

$X_E = 1-[P_{CRIT}]^{\frac{\gamma-1}{\gamma}}$ for choked flow

and

$P_{CRIT} = \left[\frac{2}{\gamma+1}\right]^{\frac{\gamma}{\gamma-1}}$

The derivation of Z and H*** os given in Appendix B.

The expression for Φ, the flow function, for unchoked flow is

$$\Phi = \sqrt{\left(\frac{2\gamma}{\gamma-1}\right)\left(\frac{P}{P_{TO}}\right)^{\frac{2}{\gamma}} - \left(\frac{P}{P_{TO}}\right)^{\frac{\gamma+1}{\gamma}}} \quad \text{(A-46)}$$

and for choked flow is

$$\Phi = \left[\frac{2}{\gamma+1}\right]^{\frac{1}{\gamma-1}} \sqrt{\frac{2\gamma}{\gamma+1}} \quad \text{(A-47)}$$

After calculating for each streamline, the flow rate is integrated from hub to tip and the resulting value is compared with $\dot{m}_{reqd}$. If the two values of flow rate agree to within a specified tolerance (see Table A-IV) continuity is considered to be satisfied. Then, after calculating the total percentage of mass flow between adjacent streamlines, subroutine FLOWR returns to the main program.

If the flow rates are not within tolerance the program checks to see if the actual mass flow is to high. If it is to high, the value of the axial velocity is lowered proportionally to the difference between the actual and required flow rates.

If the actual flow rate is too low, the procedure is more complicated. First, the flow is checked to determine whether choking has occurred. Streamlines one and five are checked. If the flow is in fact choked at those streamlines, the inlet Mach number is lowered and the program loops back to recompute the reference mass flow rate and repeat the complete procedure.

If the flow is not choked, the axial velocity is raised proportionally to the difference between actual and required flow rates and subroutine FLOWR returns to the main program.

A-2.8 Calculation of the Rotor Inlet Conditions

Continuity having been satisfied through the stator, the rotor relative inlet conditions are calculated. In subroutine ROTO1, the following expressions are used:

$$U = \frac{\omega R}{12} \qquad \text{(A-48)}$$

$$U_2 = \frac{\omega}{12} \cdot \frac{R_{STATOR}}{R_{ROTOR}} \qquad \text{(A-49)}$$

$$W_{u_1} = V_{u_1} - U \qquad \text{(A-50)}$$

$$\beta_1 = TAN^{-1}\left[\frac{W_{u_1}}{V_{a_1}}\right] \qquad \text{(A-51)}$$

$$W_1 = \frac{V_{a_1}}{\cos \beta_1} \qquad \text{(A-52)}$$

$$W_1 = \sqrt{V_{R_1}^{2} + W_1^{2}} \qquad \text{(A-53)}$$

$$T_{TE} = \frac{(T_1 + W_1)^2}{2 g_c J c_p + \left(\frac{U_2^2 - U_1^2}{2 g_c J c_p}\right)} \qquad \text{(A-54)}$$

$$P_{TE} = P_1 \left[\frac{T_{TE}}{T_1}\right]^{\frac{\gamma}{\gamma - 1}} \qquad \text{(A-55)}$$

$$H_E = (T_{TE})(.24) \tag{A-56}$$

Where T_{TE}, P_{TE} and H_E are equivalent temperature, pressure and enthalpy respectively.

A-2.9 Calculation of the Rotor Exit Conditions

Calculation of the rotor exit properties follows the same procedure as was used to compute the stator exit properties. The process is outlined here with notable differences explained. Subroutine ROTO2 calculates the rotor exit properties. A flowchart of ROTO2 is given in Fig. A-9.

The first step in ROTO2 is to solve the equation of motion for each streamline. The equation of motion in terms of relative quantities is

$$\frac{d(\ln Y_2^2)}{dX_2^2} = -\cos^2\beta_2 \left[2K r_m \frac{\delta r}{L^2} - \frac{L^2 + \left(\frac{\Delta R}{2}\right)^2}{L^2} \cdot \frac{ds^*}{dX}\right] - 2\,\mathrm{TAN}\,\beta_2 \frac{d\beta_2}{dX_2} - \frac{2}{X_2}\,\mathrm{SIN}^2\beta_2 - \frac{4U_m \cos\beta_2\,\mathrm{SIN}\,\beta_2}{Y_2^2\,Va_2^2}$$

$$- \frac{2U_m U_2 \cos^2\beta_2}{Y_2^2\,Va_2^2} + \frac{C_1 \cos^2\beta_2}{Y_2^2\,Va_2^2} \cdot \frac{dH_E}{dX_2} +$$

$$\left[1 - \frac{C_1 H_E \cos^2\beta_2}{Y_2^2\,Va_2^2}\right] \cdot \frac{ds_2^*}{dX_2} \tag{A-57}$$

At this point in the calculation, streamline curvature is neglected. Hence, Eq. (A-57) reduces to

$$\frac{d(\ln Y_2^{2})}{dX_2} = -2\,\mathrm{TAN}\,\beta_2\,\frac{d\beta_2}{dX_2} - \frac{2}{X_2}\,\mathrm{SIN}^2\beta_2 - \frac{4U_m\cos\beta_2\,\mathrm{SIN}\,\beta_2}{Y_2 Va_2} - \frac{2U_m U_2\cos^2\beta_2}{Y_2^{2} Va_2^{2}} + \frac{C_1\cos^2\beta_2}{Y_2^{2} Va_2^{2}}\,\frac{dH_E}{dX_2} + \left[1 - \frac{C_1 H_E\cos^2\beta_2}{Y_2^{2} Va_2^{2}}\right]\frac{dS_2}{dX_2} \qquad \text{(A-58)}$$

The derivation of Eq. (A-57) is contained in Appendix B. Equation (A-55) is similar in form to Eq. (A-10). Hence, the method of solution is identical to that employed by subroutine STATR. However, after solving the equation, the value of Y_2 at each streamline is examined to determine whether or not it falls into the range $.2<Y_2<2.0$. Values of Y_2 greater than 2.0 are set equal to 2.0 while those less than .2 are set equal to .2. Successive values of Y_2 at each streamline are compared, and when the values of successive iterations are within a specified tolerance (see Table A-IV), the iteration ends. The values of Y_2 are used to calculate the rotor exit conditions using the following equations:

$$Va_2 = Va_2(3)\,Y_2 \qquad \text{(A-59)}$$

$$W_2 = \frac{V_{a_2}}{\cos\beta_2} \tag{A-60}$$

$$W_{R_2} = \frac{(-V_{a_2})\cdot D\cdot CL}{2} \tag{A-61}$$

$$T_2 = T_{TE} - \frac{W_2^{\,2}}{2 g_c J c_p} \tag{A-62}$$

$$V_{u_2} = V_{a_2} \, \mathrm{TAN}\, \beta_2 \tag{A-63}$$

$$W_{u_2} = V_{u_2} + U \tag{A-64}$$

$$T_{2S} = T_{TE} - \frac{T_{TE} - T_2}{1 - \rho_R} \tag{A-65}$$

$$P_2 = P_{TE} \left[\frac{T_{2S}}{T_{TE}} \right]^{\frac{\gamma}{\gamma - 1}} \tag{A-66}$$

Subroutine ROTO2, then returns to the main program.

After calculating the rotor outlet conditions, the rotor loss coefficients are computed. Subroutine ALOS2

calculates the rotor loss coefficients following the process used in subroutine ALOS1 for the stator losses. The principle exception is that a tip clearance loss is also calculated and added to the total loss coefficient. The tip clearance loss coefficient is obtained from subroutine ALEAK which uses a straight line approximation to the curve shown in Fig. A-10. Subroutine ALOS2 also computes values of ξ^* and one of the three refinements to ξ_R.

Subroutine FLOWR is called to check continuity at the rotor exit. If continuity is satisfied, the program continues. If not, the same procedure is followed as previously explained for the stator outlet (Fig. A-1).

A-2.10 Accounting for Streamline Curvature

All calculations to this point have neglected streamline curvature and assumed that the streamlines remain fixed through the stator and rotor (Fig. A-11). The radial shift in a streamline between stator inlet and rotor outlet can be written as

$$\Delta R = R_{\substack{\text{STATOR}\\ \text{INLET}}} - R_{\substack{\text{ROTOR}\\ \text{OUTLET}}} \qquad \text{(A-67)}$$

This is the net radial shift in a streamline between stations '0' (stator inlet) and '2' (rotor outlet). It is shown in Section 16.4 of Ref. [5] that the radial shift in a streamline between the stator and the rotor (station 1) can be written as

$$\delta R = R_{\substack{\text{STATOR}\\ \text{OUTLET}}} - \frac{1}{2}\left[R_{\substack{\text{STATOR}\\ \text{INLET}}} - R_{\substack{\text{ROTOR}\\ \text{OUTLET}}}\right] \tag{A-68}$$

The angle between the meridional velocity V_m and the axial velocity V_1 is λ. The radial velocity V_r can be expressed as

$$V_R = V_a \,\mathrm{TAN}\, \lambda \tag{A-69}$$

and from Fig. 16(1) of Ref.[5], it follows that

$$\mathrm{TAN}\, \lambda = \frac{-\Delta R}{2L} \tag{A-70}$$

Using Eq. (A-68) in Eq. (A-67),

$$V_R = -V_a \frac{\Delta R}{2L} \tag{A-71}$$

where $\frac{\Delta R}{2L}$ = Average streamline slope

Also, from using Eq. (A-68)

$$\cos \lambda = \frac{2L}{\sqrt{\Delta R^2 + (2L)^2}} \tag{A-72}$$

Rearranging;

$$\cos \lambda = \sqrt{\frac{L^2}{L^2 + \left(\frac{\Delta R}{2}\right)^2}} \tag{A-73}$$

The remaining term used in the calculation of streamline curvature (Section 16-4 of Ref. [5]) is

$$K \frac{\delta R}{L^2}$$

where K is the so called curvature factor. It usually has a value between 4 and 6 and in the program its value is taken to be 5. Having calculated cosλ, ΔR and δR, the program repeats the solution process. However, the only quantity which is unchanged is the reference mass flow rate $\dot{m}_{ref}$. In subroutine STATR the equation of motion is solved, this time accounting for streamline curvature. The same is true in subroutine ROTO2.

The flow path of the program is identical to the section which did not account for streamline curvature. Next, the program computes an average pressure ratio at the rotor outlet using the expression

$$\frac{P_2}{P_{TO}} = \left(\frac{P_2}{P_{TO}}\right)_{\substack{\text{STREAMLINE}\\1}} + \frac{1}{4}\left[\left(\frac{P_2}{P_{TO}}\right)_{\substack{S.L.\\2}} \left(\frac{P_2}{P_{TO}}\right)_{\substack{S.L.\\3}} + \left(\frac{P_2}{P_{TO}}\right)_{\substack{S.L.\\4}} + \left(\frac{P_2}{P_{TO}}\right)_{\substack{S.L.\\5}}\right] \qquad \text{(A-74)}$$

If this pressure ratio is within a specified tolerance to the actual pressure ratio (which is input data) the program

proceeds to the final stage of the calculations. If not, the inlet mach number is adjusted by an amount which depends on the difference between the calculated and specified pressure ratios. If the calculated pressure ratio is too high, the Mach number is lowered using

$$M_o = M_o - \frac{\text{Pressure Ratio Difference}}{18} \qquad \text{(A-75)}$$

If the computed pressure ratio is too low, the Mach number is raised using

$$M_o = M_o + \frac{\text{Pressure Ratio Difference}}{18} \qquad \text{(A-76)}$$

In both cases, the program loops back to subroutine CHAN and proceeds to compute a new reference mass flow rate based on the new value of the inlet Mach number. The entire process is then repeated until the pressure ratios agree within the specified tolerance.

A-2.11 Final Calculations

Stator and rotor outlet conditions not previously calculated are computed as follows:

$$\alpha_2 = \mathrm{TAN}^{-1}\left[\frac{V_{u_2}}{V_{a_2}}\right] \qquad \text{(A-77)}$$

$$V_2 = \frac{V_{a_2}}{\cos \alpha_2} \qquad \text{(A-78)}$$

$$V_2 = \sqrt{V_2^2 + W_{R_2}^2} \qquad \text{(A-79)}$$

$$\Delta h = \frac{U V_{u_1} - U_2 V_{u_2}}{g_c J} \qquad \text{(A-80)}$$

$$T_{T_2} = T_{T0} - \frac{\Delta h}{C_p} \qquad \text{(A-81)}$$

$$P_{T_2} = P_2 \left[\frac{T_{T_2}}{T_2} \right]^{\frac{\gamma}{\gamma-1}} \qquad \text{(A-82)}$$

$$P_{T_1} = P_1 \left[\frac{T_{T0}}{T_1} \right]^{\frac{\gamma}{\gamma-1}} \qquad \text{(A-83)}$$

$$T_{2_{is}} = T_{T0} \left[\frac{P_2}{P_{T0}} \right]^{\frac{\gamma-1}{\gamma}} \qquad \text{(A-84)}$$

ROTOR EXIT
RELATIVE MACH # $= \dfrac{W_2}{\sqrt{\gamma R g_c T_2}}$ (A-85)

$$T_{T_{1S}} = T_{TO} \left[\frac{P_{T_2}}{P_{TO}} \right]^{\frac{\gamma-1}{\gamma}} \qquad \text{(A-86)}$$

$$\eta_{T-T} = \frac{T_{TO} - T_{T_2}}{T_{TO} - T_{T_{1S}}} \qquad \text{(A-87)}$$

$$\eta_{T-S} = \frac{T_{TO} - T_{T_2}}{T_{TO} - T_{2_{1S}}} \qquad \text{(A-88)}$$

$$\text{Stator Blade Efficiency} = \frac{T_{TO} - T_1}{T_{TO} - T_{1_{S}}} \qquad \text{(A-89)}$$

$$\text{Rotor Blade Efficiency} = \frac{T_{TE} - T_2}{T_{TO} - T_{2_{1S}}} \qquad \text{(A-90)}$$

$$r^* = \frac{T_{1_{S}} - T_{2_{1S}}}{T_{TO} - T_{2_{1S}}} \qquad \text{(A-91)}$$

$$\text{Head Coefficient} = \frac{2 g_c J (T_{TO} - T_{2_{1S}})}{U^2} \qquad \text{(A-92)}$$

$$\text{Blade-Jet Ratio} = [\text{Head Coefficient}]^{-1} \qquad \text{(A-93)}$$

$$\text{Stator Exit Relative Mach \#} = \frac{W_1}{\sqrt{\gamma R g_c T_1}} \qquad \text{(A-94)}$$

The turbine horsepower is obtained by integration. The Δh term at each streamline is weighted by the percentage of mass flow at that streamline. The product is then integrated from hub to tip and result, $\Delta\bar{h}$, is used in the turbine horsepower equation

$$H.P. = \frac{\Delta\bar{h} \cdot J \cdot \dot{m}}{550} \qquad \text{(A-95)}$$

The moment is calculated using

$$M = \frac{(H.P.)(550)}{\omega} \qquad \text{(A-96)}$$

Referred horsepower, moment, mass flow and RPM are calculated using

$$H.P._{REF} = \frac{H.P.}{\theta\,\delta} \qquad \text{(A-97)}$$

$$M_{REF} = \frac{M}{\delta} \qquad \text{(A-98)}$$

$$\dot{m}_{REF} = \frac{\dot{m}\,\theta}{\delta} \qquad \text{(A-99)}$$

$$RPM_{REF} = \frac{RPM}{\theta} \qquad \text{(A-100)}$$

where

$$\Theta = \frac{T_{TO}}{518.4}$$

$$\delta = \frac{P_{TO}}{14.7}$$

The values of the total-static efficiency, total-total efficiency, total-static pressure ratio, total-total pressure ratio, head coefficient, blade/jet ratio, r* and inlet mach number are then averaged.

With all calculations completed, the results are printed under the heading "STATOR SOLUTION", "ROTOR SOLUTION", and "OVERALL TURBINE CHARACTERISTICS".

TABLE A-I

TURBINE GEOMETRIC INPUT DATA (STATOR)
(see Figure A-2; Dimensions in inches)

FORTRAN SYMBOL	DESCRIPTION
ZS	Number of blades
RS(1)	Hub radius at stator outlet
RS(3)	Mean radius at stator outlet
RS(5)	Tip radius at stator outlet
C	Blade chord (mean)
CI	Blade chord (hub)
CO	Blade chord (tip)
E	Blade curvature (mean)
EI	Blade curvature (hub)
EO	Blade curvature (tip)
T	Maximum blade thickness (mean)
TI	Maximum blade thickness (hub)
TO	Maximum blade thickness (tip)
TE	Projected T.E. thickness (mean)
TEI	Projected T.E. thickness (hub)
TEO	Projected T.E. thickness (tip)
TN	Normal T.E. thickness (mean)
TNI	Normal T.E. thickness (hub)
TNO	Normal T.E. thickness (tip)
A1(1-10)	Ten values of throat diameter at 10 equally spaced radii

FORTRAN SYMBOL	DESCRIPTION
AL	Blade camber line length (mean)
ALI	Blade camber line length (hub)
ALO	Blade camber line length (tip)
RC(1)	Hub radius at stator inlet
RC(3)	Mean radius at stator inlet
RC(5)	Tip radius at stator inlet

TABLE A-II

TURBINE GEOMETRIC INPUT DATA (ROTOR)
(see Figure A-2; Dimensions in inches)

FORTRAN SYMBOL	DESCRIPTION
ZR	Number of blades
RR(1)	Hub radius
RR(3)	Mean radius
RR(5)	Tip radius
CR	Blade chord (mean)
CIR	Blade chord (hub)
COR	Blade chord (tip)
ER	Blade curvature (mean)
EIR	Blade curvature (hub)
EOR	Blade curvature (tip)
TR	Maximum blade thickness (mean)
TIR	Maximum blade thickness (hub)
TOR	Maximum blade thickness (tip)
TER	Projected T.E. thickness (mean)
TEIR	Projected T.E. thickness (hub)
TEOR	Projected T.E. thickness (tip)
TNR	Normal T.E. thickness (mean)
TNIR	Normal T.E. thickness (hub)
TNOR	Normal T.E. thickness (tip)
TIPC	Tip clearance

FORTRAN SYMBOL	DESCRIPTION
A2(1-10)	10 values of throat diameter at 10 equally spaced radii
ALR	Blade camber line length (mean)
ALIR	Blade camber line length (hub)
ALOR	Blade camber line length (tip)
CV	Axial distance between stations
CK	Curvature Factor

TABLE A-III

TURBINE OPERATING CONDITIONS (INPUT DATA)

FORTRAN SYMBOL	DESCRIPTION
AMC	Assumed inlet Mach number
AMS	Assumed stator exeit Mach number (absolute)
AMR	Assumed stator exit Mach number (relative)
PTO	Total inlet pressure (P_{TO})
TTO	Total inlet temperature (T_{TO})
PR	Total-static pressure ratio
RPM	Operating speed (RPM)
VA1(3)	Assumed axial velocity in stator
VA2(3)	Assumed axial velocity in rotor

TABLE A-IV

SPECIAL INPUT DATA

FORTRAN SYMBOL	DESCRIPTION
TOL 1	Tolerance for convergence of equation of continuity
TOL 2	Tolerance for between-S.L. continuity (not used)
TOL 3	Tolerance in pressure ratio convergence
TOL 4	Tolerance in equation of motion convergence

TABLE A-V

PROGRAM CONTROL PARAMETERS

FORTRAN SYMBOL	POSSIBLE VALUE	EFFECT/MEANING
IND	1	Prints results in subroutines STATR, FLOWR, ROTO2
	1	No printing in the above
ICL	1	Rotor is shrouded
	1	Rotor not shrouded
ICOZ	1	$\xi = \xi_0$
	6	$\xi = \xi$ (Y Pressure Ratio)
	8	$\xi = \xi_{M=.8}$
ICON	1	$\xi = .5\S_{\mathrm{TOTAL}}$
	2	$\xi = \xi_{\mathrm{PROFILE}}$
	3	$\xi = \xi_{\mathrm{TOTAL}}$

TABLE A-VI

FORTRAN SYMBOLS IN THE MAIN PROGRAM

FORTRAN SYMBOLS	DESCRIPTION
BESP	$\beta^* = [1 + \frac{\gamma-1}{2} \cdot (.8)^2]^{\frac{\gamma-1}{\gamma}}$
OI	Stator throat opening (hub)
OO	Stator throat opening (tip)
OIR	Rotor throat opening (hub)
OOR	Rotor throat opening (tip)
O	Stator throat opening (mean)
OR	Rotor throat opening (mean)
ANG2I	Stator gas outlet angle (hub)
ANG2O	Stator gas outlet angle (tip)
BETAI	Rotor gas outlet angle (hub)
BETAZ	Rotor gas outlet angle (tip)
G	Grav. constant, 32.174 $\frac{\text{FT.LBM}}{\text{LBF.sec}^2}$
CJ	778.16 FT.LBF/BTU
EXP1	$\gamma/\gamma - 1$
EXP2	$\gamma-1/\gamma$
ERRE	Gas constant, 53.3459 $\frac{\text{FT.LBF}}{\text{LBM.oR}}$
EMME	Molecular mass, 28.970 LBM/LB MOLE
GAM	γ, Ratio of specific heats
ETAT	Total-total efficiency
ETAI	Total-static efficiency
ETAS	Stator blade efficiency

FORTRAN SYMBOL	DESCRIPTION
ETAR	Rotor blade efficiency
RSTAR	Theoretical degree of reaction
ALOS	Head coefficient
BLAJE	Blade/jet ratio
DR1	Radial shift of steamlines
AMW1	Stator exit relative Mach Number
AMS1	Stator exit absolute Mach Number
AMV2	Rotor exit absolute Mach Number
AMR2	Rotor exit relative Mach Number
DELH	Δ
HP	Horsepower
AMOM	Moment
THETA	θ
DELTA	δ
HP1	Referred H.P.
AMOM1	Referred moment
RPM1	Referred RPM
WLBM1	Referred mass flow rate
ETA5	Average total-static efficiency
BETA6	Average total-total pressure ratio
ETA6	Average total-total efficiency
AKIS5	Average head coefficient
RSTAR5	Average theoretical degree of reaction

TABLE A-VII

FORTRAN SYMBOLS IN SUBROUTINE CHAN

FORTRAN SYMBOLS	DESCRIPTION
TTO	T_{TO}, total temp. at station 0
AMC	Inlet Mach number
PTO	P_{TO}, total pressure at station 0
RC (I)	Streamline radii at station 0
WLBM	$\dot{M}$, required mass flow, ρAV
TC	Static temperature
VC	Velocity
PC	Static pressure
RHO	ρ, density of air
WCHAN	$\dot{M}_{REF}$, reference mass flow
WPERO	% of $\dot{M}$ at each streamline

TABLE A-VIII

FORTRAN SYMBOLS IN SUBROUTINE STATR

FORTRAN SYMBOL	DESCRIPTION
ALFA1	Stator gas outlet angle
X	Ratio of streamline radius/ mean radius
AMS	Mach Number at station 1
T	Static temperature
P	Static pressure
V1	Absolute velocity
VA1	Axial velocity
Y	Ratio of axial velocity to mean axial velocity
S	Entropy
DSDX	Entropy gradient between streamlines
VU1	Tangential velocity
PRAT	(Total-static pressure ratio)$^{-1}$
T1IS	T_{1IS}
DALF	$\frac{d\alpha}{dx}$
RSF	Mean stator radius
DELR	$R_{\text{Stator in}} - R_{\text{rotor out}}$
ZETAPS	$\S_p$
ZETAS	$\S_s$
VR1	Radial velocity

TABLE A-IX

FORTRAN SYMBOLS IN SUBROUTINE TRAU2

FORTRAN SYMBOL	DESCRIPTION
CSIP	X_p, correction to
R	$\S_{po}$, initial profile loss coefficient
ANG1	Gas outlet angle
ANG2	Gas inlet angle
R1	X_m, Mach No. correction
R3	$\S_R$, remaining loss coefficient
R2	$\S_W$, loss coefficient due to wall friction
RPRO	$\S_p$, total profile loss coefficient
CL	Rotor tip clearance
YCL	Tip clearance loss coefficient
RTOT	Total loss coefficient
T	Blade spacing
DEZ	Normal trailing edge thickness
HM	Blade height
CSID	X_δ, trailing edge thickness correction factor
PSID	$\S_f$, loss coefficient due to fan losses
PSIF	$\S_m$, loss coefficient due to mixing and separation
UM	Tip speed

TABLE A-X

FORTRAN SYMBOLS IN SUBROUTINE FLOWR

FORTRAN SYMBOL	DESCRIPTION
PRATCR	Critical pressure ratio
PHICR	Φ_{CRIT}, critical flow function
HSTAR	H***, energy parameter
XI	Ξ, area reduction coefficient
PHI	Φ, flow function (unchoked flow)
ARAT	Streamline throat DIA/mean throat DIA
SUM 1,2,3,4	Successive values of the flow integral
AS	Mean stator throat diameter
AR	Mean rotor throat diameter
WREQ	$\dot{M}$ required to satisfy continuity
WSUM	$\dot{M}$ calculated
WPER	% of $\dot{M}$ at each streamline

TABLE A-XI

FORTRAN SYMBOLS IN SUBROUTINE ROTO1

FORTRAN SYMBOL	DESCRIPTION
OMEG	ω, wheel speed (RAD/sec)
U	$\omega \cdot R_{\text{stator mean}}$
U2	$\omega \cdot \frac{R_{\text{rotor mean}}}{R_{\text{stator mean}}}$
WU1	$W\mu_1$ see figure A-3
BETA1	β_1, see figure A-3
W1	W_1, see figure A-3
TTE	Equivalent temperature
PTE	Equivalent pressure
HE	Equivalent enthalpy
ZETAR	$\S_R$ rotor loss coefficient
ZETAPR	$\S_p$, rotor profile loss coefficient
DHEDX	Enthalpy gradient between streamlines
DSDX	Entropy gradient between streamlines

TABLE A-XII

FORTRAN SYMBOLS IN SUBROUTINE ROTO2

FORTRAN SYMBOL	DESCRIPTION
BETA2	β_2, see figure A-3
DBETDX	$\frac{d\beta}{dx}$ between adjacent streamlines
VA2	V_{a_2}, axial velocity
W2	W_2, see figure A-3
CL	Axial distance between stations
WR2	Radial component of velocity
WU2	Wu_2 , see figure A-3
VU2	Vu_2, see figure A-3
AMR	Relative Mach No. at rotor exit
T2	T_2
T2S	T_{2s}
P2	P_2
PRAT2	[Total-static pressure ratio]$^{-1}$

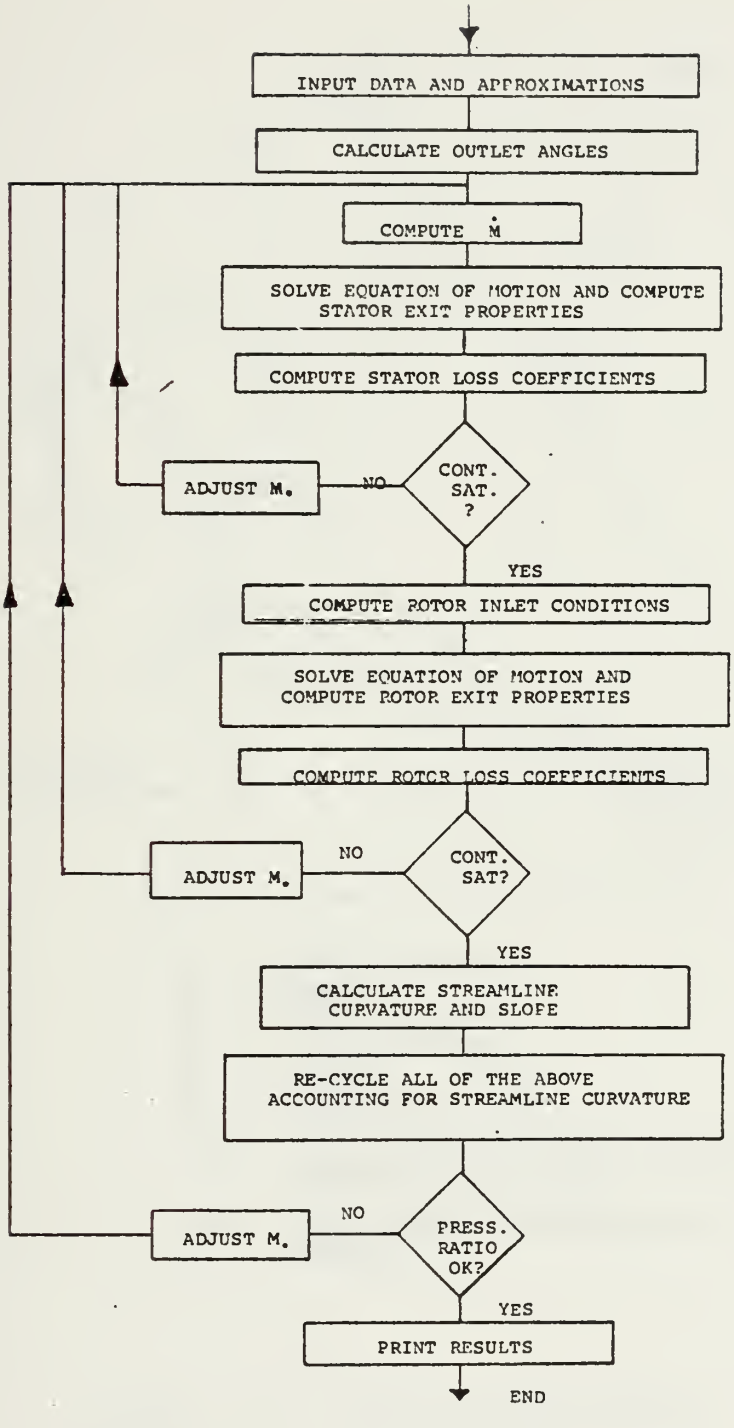
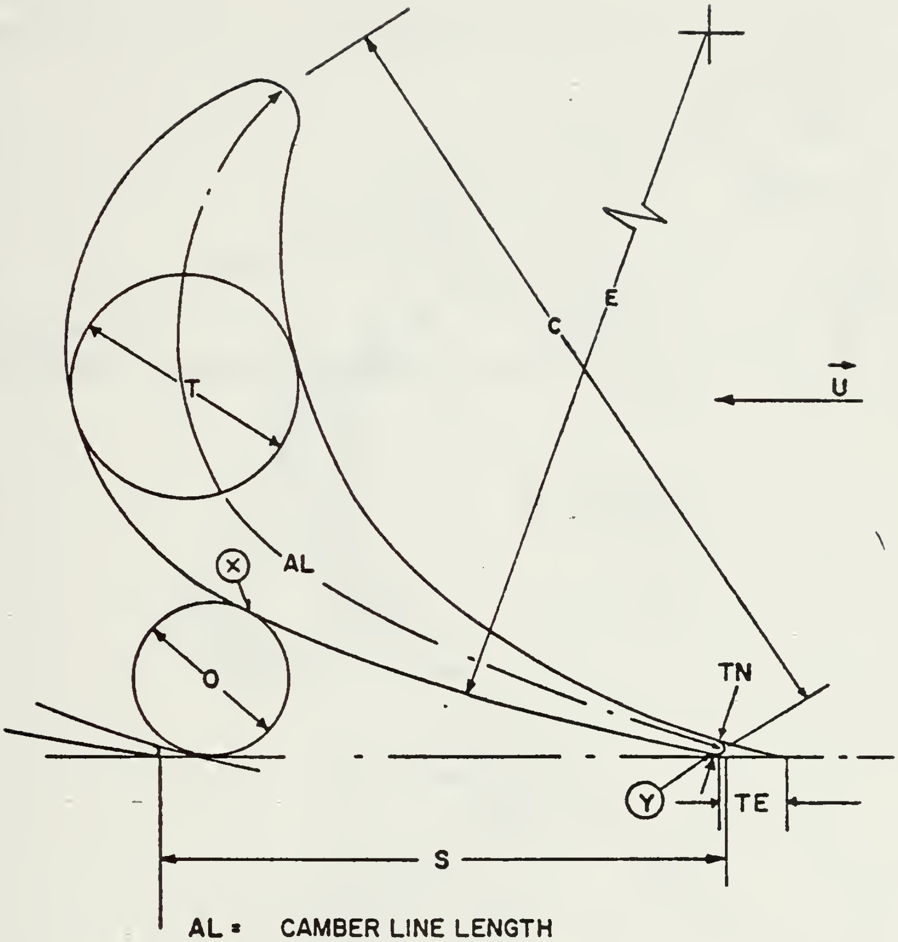

INPUT DATA AND APPROXIMATIONS
CALCULATE OUTLET ANGLES
COMPUTE $\dot{M}$
SOLVE EQUATION OF MOTION AND COMPUTE STATOR EXIT PROPERTIES
COMPUTE STATOR LOSS COEFFICIENTS
ADJUST M.
NO
CONT. SAT. ?
YES
COMPUTE ROTOR INLET CONDITIONS
SOLVE EQUATION OF MOTION AND COMPUTE ROTOR EXIT PROPERTIES
COMPUTE ROTOR LOSS COEFFICIENTS
ADJUST M.
NO
CONT. SAT?
YES
CALCULATE STREAMLINE CURVATURE AND SLOPE
RE-CYCLE ALL OF THE ABOVE ACCOUNTING FOR STREAMLINE CURVATURE
ADJUST M.
NO
PRESS. RATIO OK?
YES
PRINT RESULTS
END

FIGURE A-1: PROGRAM FLOWCHART



AL = CAMBER LINE LENGTH
C = CHORD
O = THROAT DIAMETER
E = CURVATURE RADIUS
S = SPACING
T = MAXIMUM THICKNESS

TE = TRAILING EDGE THICKNESS PROJECTED IN PERIPHERAL DIRECTION

TN = TRAILING EDGE THICKNESS, NORMAL TO FLOW DIRECTION

FIGURE A-2: BLADE NOMENCLATURE

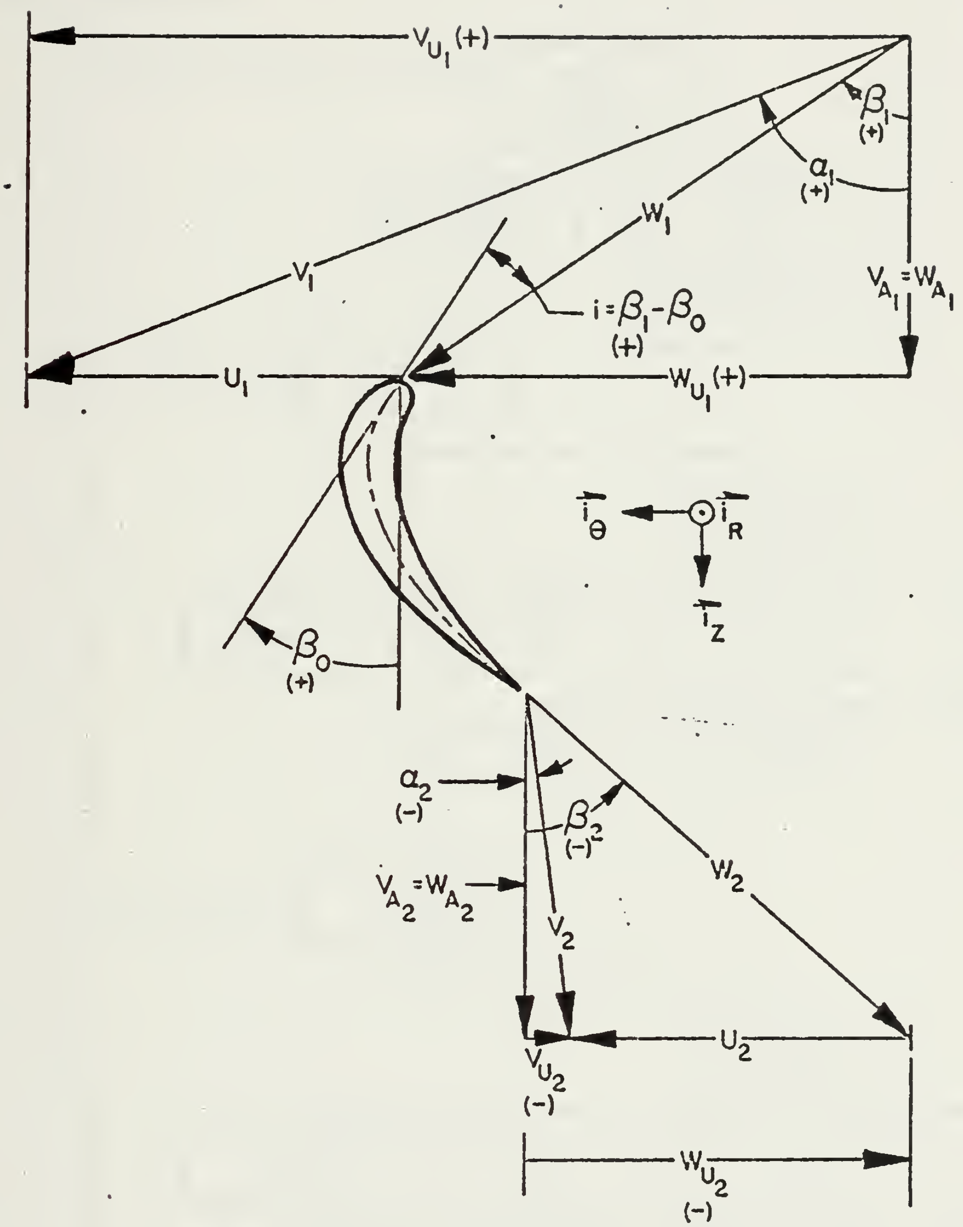


FIGURE A-3: VELOCITY DIAGRAM NOMENCLATURE

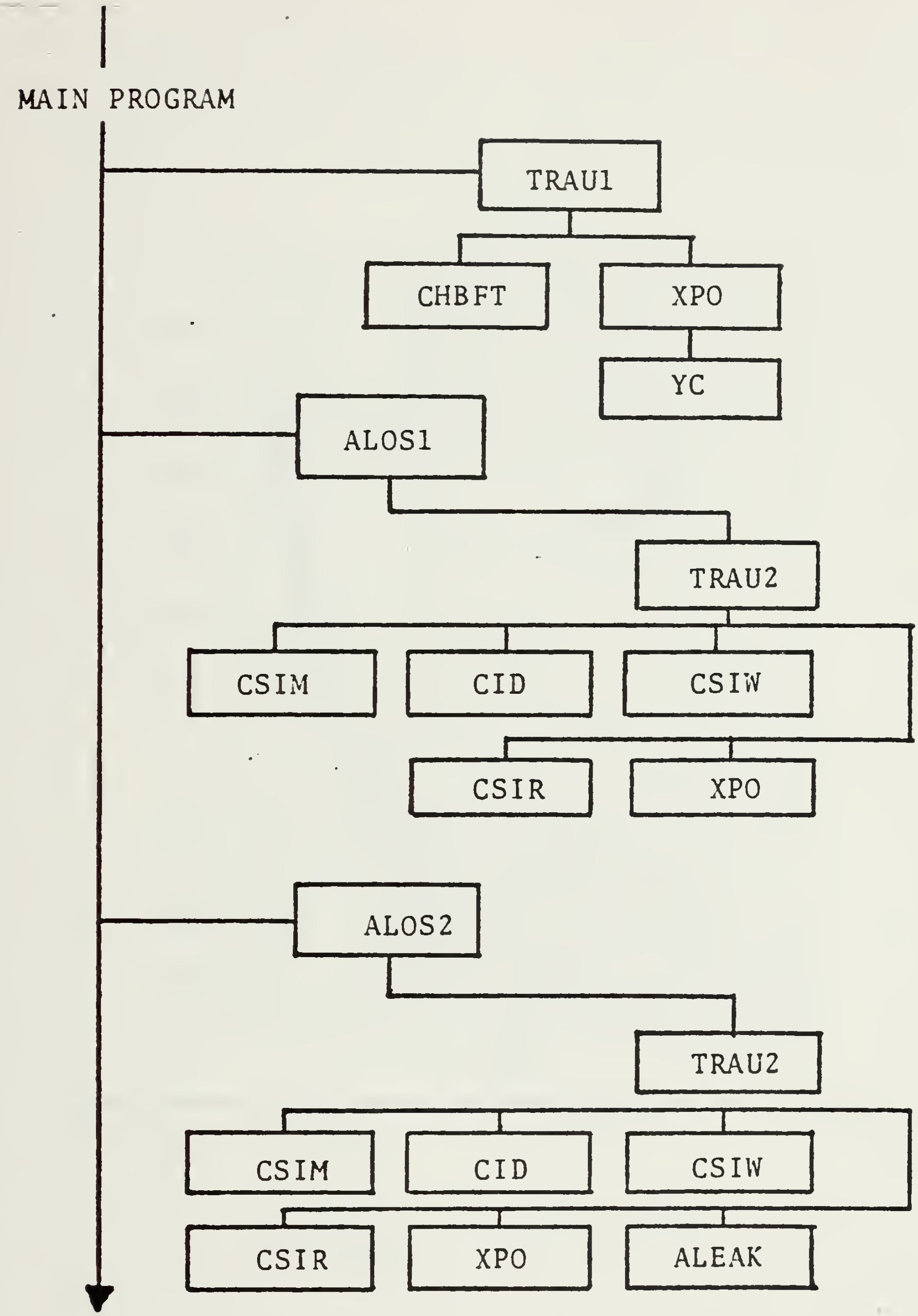


FIGURE A-4: INTERCONNECTION OF THE SUBROUTINES IN THE TRAUPEL METHOD

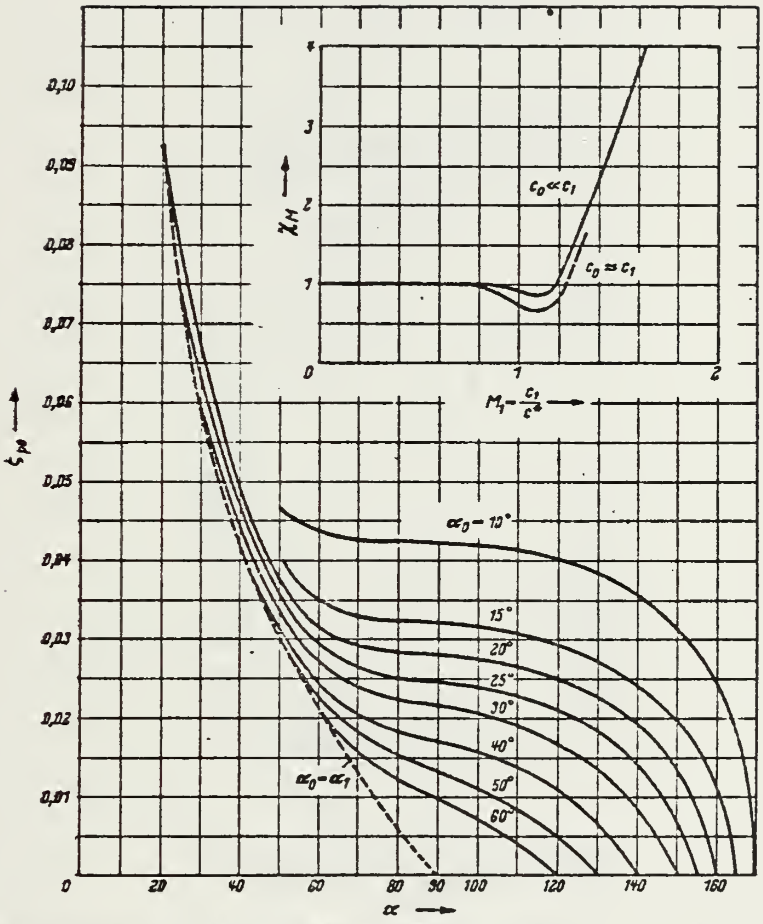


Abb. 8.4.2 Grundwert ζ_{po} des Profilverlustes für Beschleunigungsgitter und Machzahlkorrektur χ_M

FIGURE A-5: INITIAL PROFILE LOSS COEFFICIENT AND MACH NUMBER CORRECTION FROM TRAUPEL

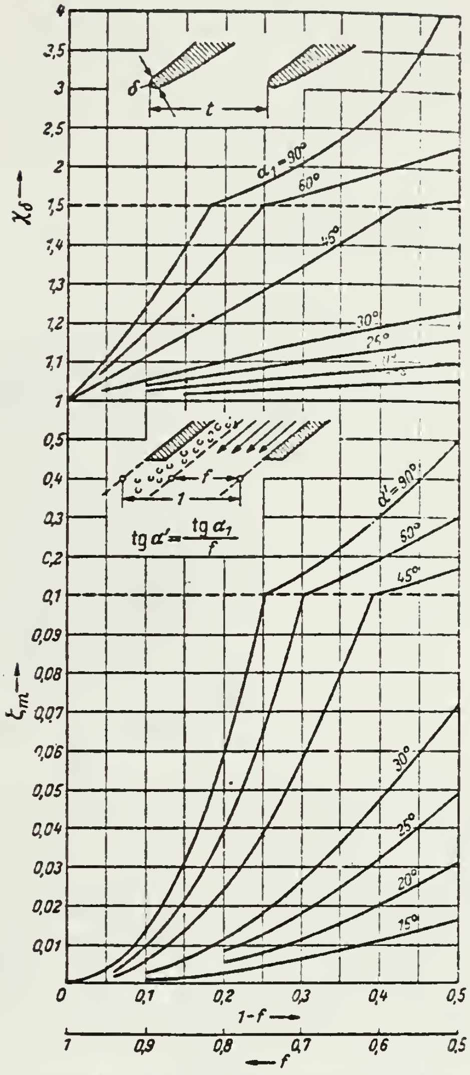


Abb. 8.4.4. Korrekturfaktor χ_δ und Mischverlust ζ_m infolge endlicher Austrittskantendicke oder Ablösung

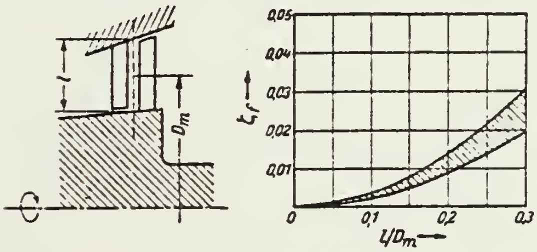


Abb. 8.4.5 Fächerverlust ζ_f

FIGURE A-6: T.E.THICKNESS CORRECTION FACTOR, MIXING LOSS COEFFICIENT AND FAN LOSS COEFFICIENT FROM TRAUPEL

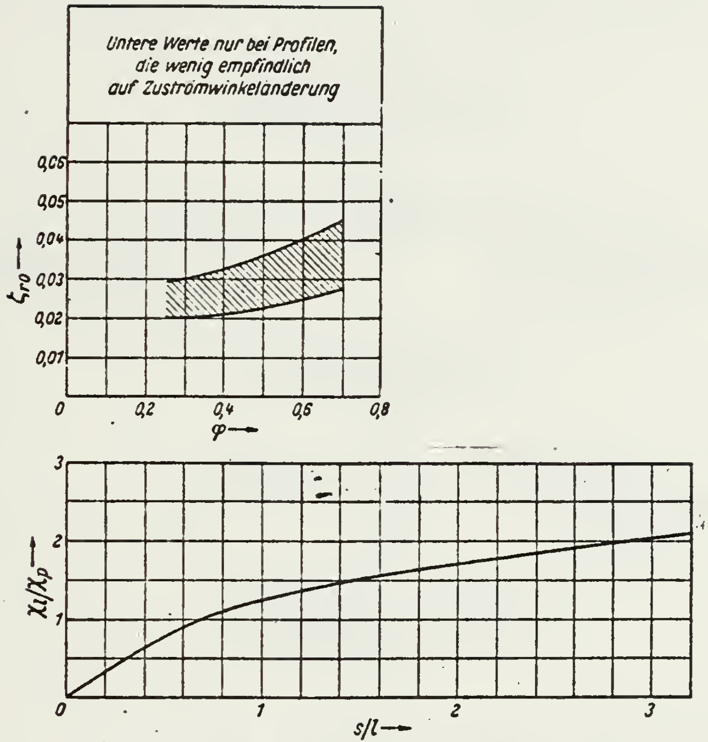


Abb. 8.4.7 Randverlust in Turbinenschaufelungen

FIGURE A-7: "REMAINING" LOSS COEFFICIENT FROM TRAUPEL

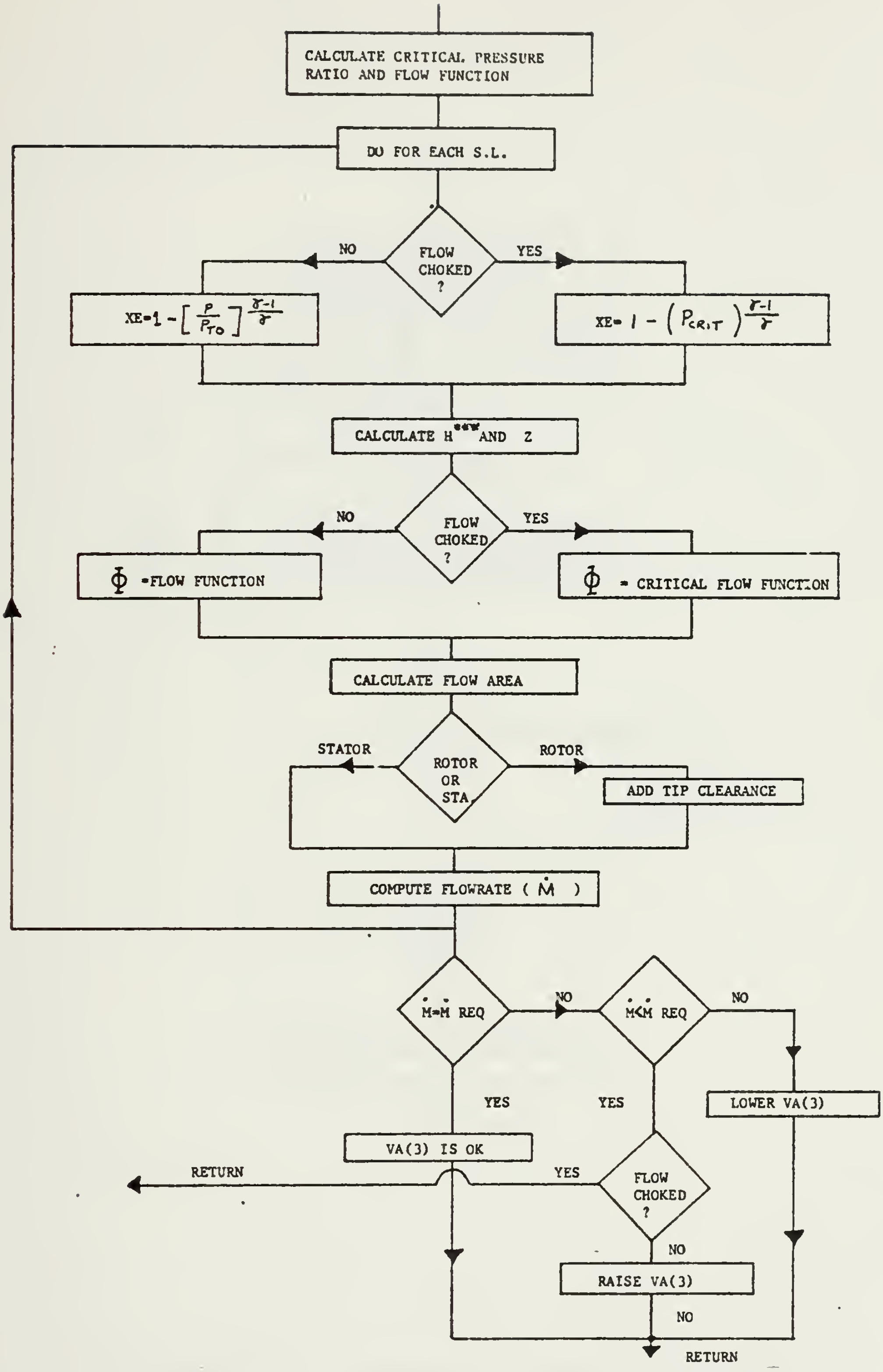

CALCULATE CRITICAL PRESSURE RATIO AND FLOW FUNCTION
DO FOR EACH S.L.
NO
FLOW CHOKED ?
YES
XE=1 - $\left[\frac{P}{P_{TO}}\right]^{\frac{\gamma-1}{\gamma}}$
XE= 1 - $\left(P_{CRIT}\right)^{\frac{\gamma-1}{\gamma}}$
CALCULATE H^{***} AND Z
NO
FLOW CHOKED ?
YES
Φ =FLOW FUNCTION
Φ = CRITICAL FLOW FUNCTION
CALCULATE FLOW AREA
STATOR
ROTOR OR STA
ROTOR
ADD TIP CLEARANCE
COMPUTE FLOWRATE ($\dot{M}$)
$\dot{M}=\dot{M}$ REQ
NO
$\dot{M}<\dot{M}$ REQ
NO
YES
YES
LOWER VA(3)
VA(3) IS OK
RETURN
YES
FLOW CHOKED ?
NO
RAISE VA(3)
NO
RETURN

FIGURE A-8: SUBROUTINE FLOWR FLOWCHART

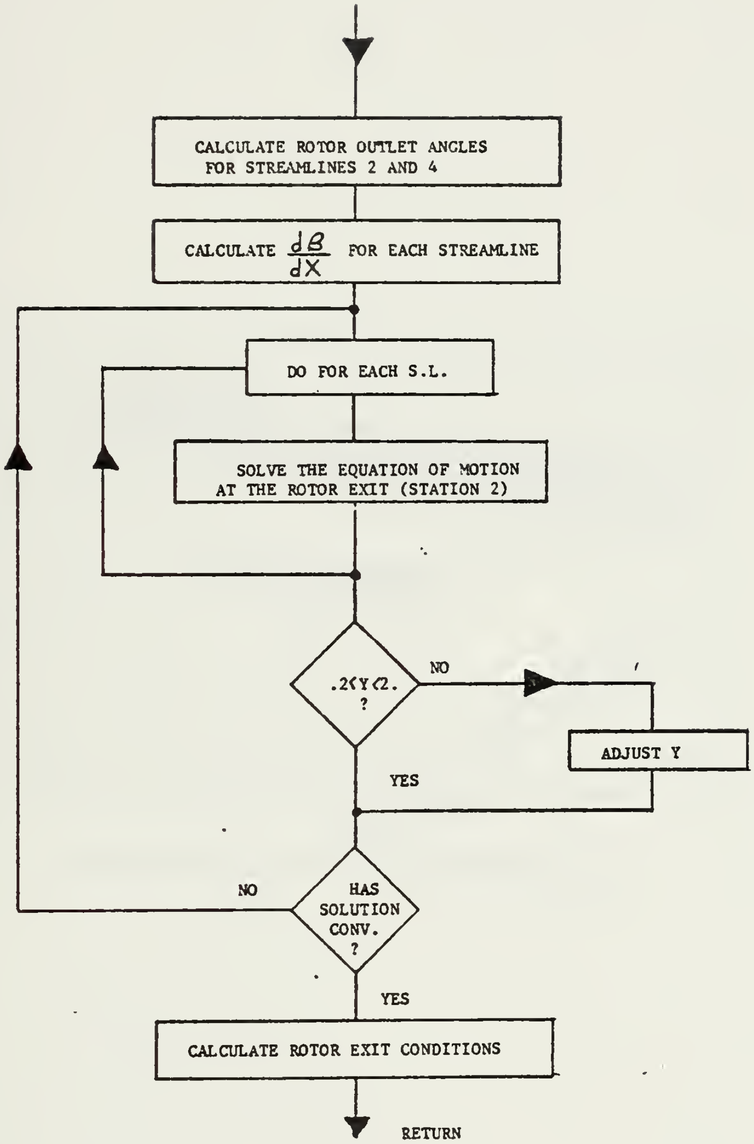

CALCULATE ROTOR OUTLET ANGLES FOR STREAMLINES 2 AND 4
CALCULATE $\frac{d\beta}{dX}$ FOR EACH STREAMLINE
DO FOR EACH S.L.
SOLVE THE EQUATION OF MOTION AT THE ROTOR EXIT (STATION 2)
.2<Y<2. ?
NO
ADJUST Y
YES
NO
HAS SOLUTION CONV. ?
YES
CALCULATE ROTOR EXIT CONDITIONS
RETURN

FIGURE A-9: SUBROUTINE ROTO2 FLOWCHART

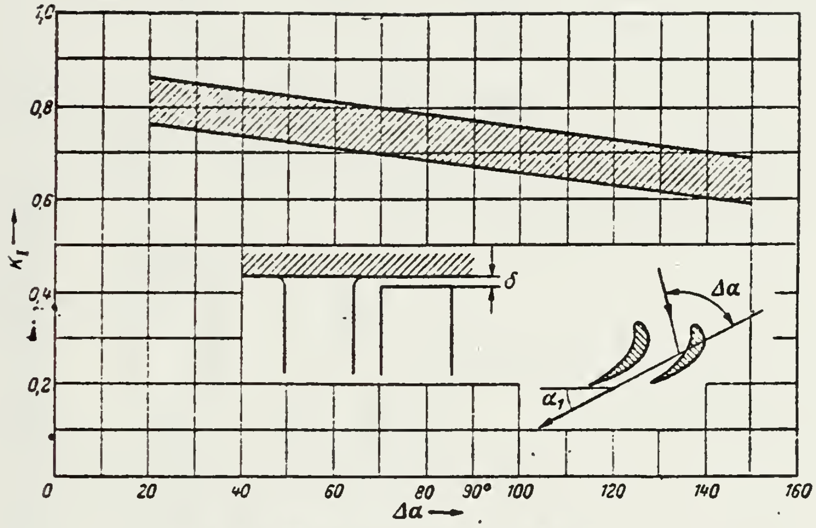


Abb. 8.4.11 Faktor K_I für Spaltverlustberechnung

FIGURE A-10: TIP LEAKAGE LOSS COEFFICIENT PLOT FROM TRAUPEL

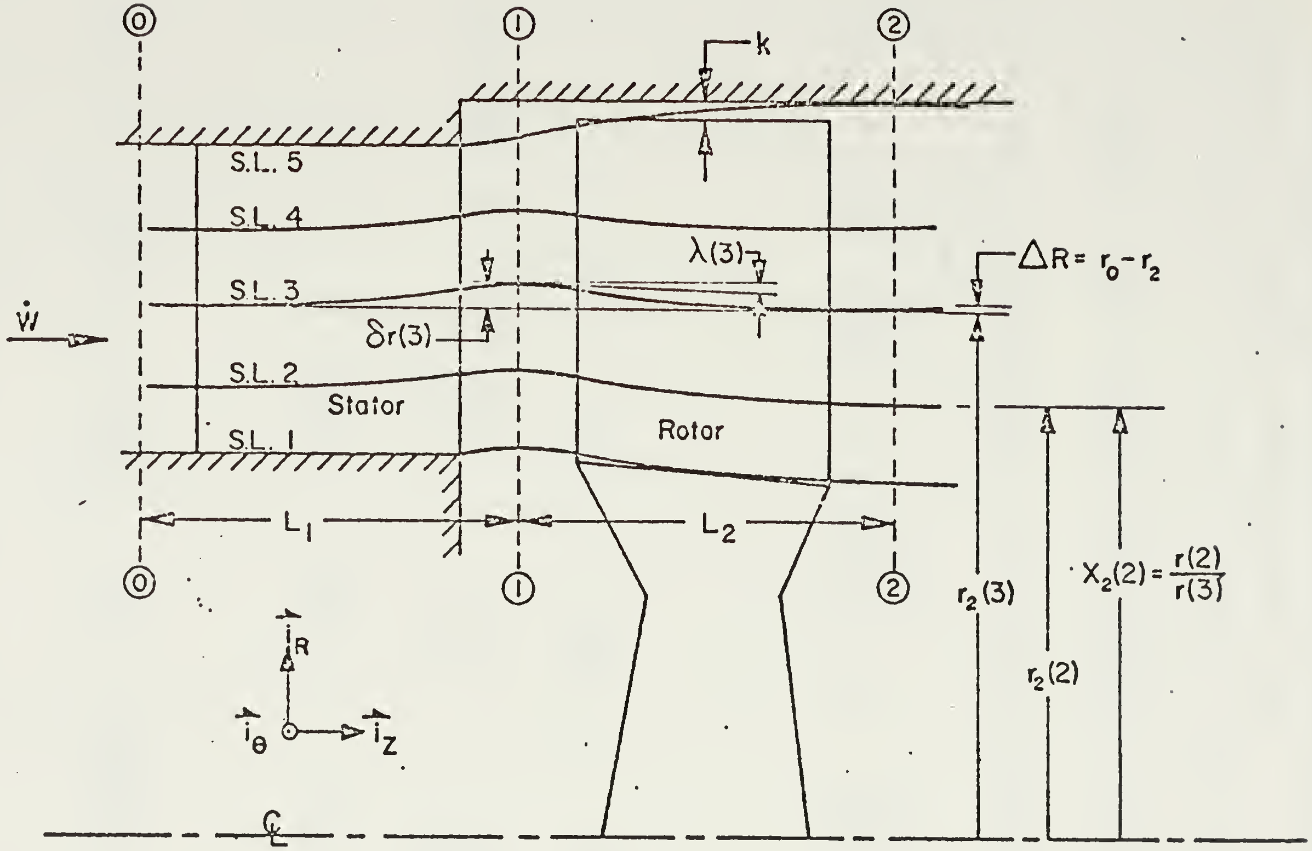


FIGURE A-11: STREAMLINE COORDINATES

APPENDIX: B

DERIVATION OF EQUATIONS USED IN THE PROGRAM

B-1. EQUATION OF MOTION FOR RELATIVE FLOW:

The equation of motion for relative flow Ref. [5] is

$$\nabla H_R = \vec{W} \times (\nabla \times \vec{W} + 2\vec{\omega}) + T \nabla S \tag{B-1}$$

Using cylindrical coordinates, the terms of EQN (B-1) may be expressed as follows:

$$\nabla H_R = \frac{i_\theta}{r} \frac{\partial H_R}{\partial \theta} + i_z \frac{\partial H_R}{\partial z} + i_r \frac{\partial H_R}{\partial r} \tag{B-2}$$

$$\nabla \times \vec{W} = \begin{vmatrix} i_\theta & \frac{i_z}{r} & \frac{i_r}{r} \\ \frac{\partial}{\partial \theta} & \frac{\partial}{\partial z} & \frac{\partial}{\partial r} \\ rW_u & W_a & W_r \end{vmatrix}$$

$$= i_\theta \left[\frac{\partial W_r}{\partial z} - \frac{\partial W_a}{\partial r} \right] + \frac{i_z}{r} \left[\frac{\partial (rW_u)}{\partial r} - \frac{\partial W_r}{\partial \theta} \right]$$

$$+ \frac{i_r}{r} \left[\frac{\partial W_a}{\partial \theta} - \frac{\partial (rW_u)}{\partial z} \right] \tag{B-3}$$

$$\vec{W} \times (\nabla \times \vec{W}) =$$

$$\begin{vmatrix} i_\theta & i_z & i_r \\ W_u & W_a & W_r \\ \left[\dfrac{\partial W_r}{\partial z} - \dfrac{\partial W_a}{\partial r}\right] & \dfrac{1}{r}\left[\dfrac{\partial (rW_u)}{\partial r} - \dfrac{\partial W_r}{\partial \theta}\right] & \dfrac{1}{r}\left[\dfrac{\partial W_a}{\partial \theta} \quad \dfrac{\partial (rW_u)}{\partial z}\right] \end{vmatrix}$$

$$= i_\theta \left[W_a \frac{1}{r}\left(\frac{\partial W_a}{\partial \theta} - \frac{\partial (rW_u)}{\partial z}\right) - W_r \frac{1}{r}\left(\frac{\partial (rW_u)}{\partial r} - \frac{\partial W_r}{\partial \theta}\right)\right] +$$

$$i_z \left[W_r \left(\frac{\partial W_r}{\partial z} - \frac{\partial W_a}{\partial r}\right) - W_u \frac{1}{r}\left(\frac{\partial W_a}{\partial \theta} - \frac{\partial (rW_u)}{\partial z}\right)\right] +$$

$$i_r \left[W_u \frac{1}{r}\left(\frac{\partial (rW_u)}{\partial r} - \frac{\partial W_r}{\partial \theta}\right) - W_a \left(\frac{\partial W_r}{\partial z} - \frac{\partial W_a}{\partial r}\right)\right]$$

(B-4)

$$\vec{W} \times 2\vec{\omega} = \left[i_\theta W_u + i_z W_a + i_r W_r \right] \times \left[i_z 2\omega \right]$$

$$= i_r (2\omega W_u) - i_\theta (2\omega W_r)$$

(B-5)

$$T\nabla S = T\left[i_\theta \frac{1}{r}\frac{\partial S}{\partial \theta} + i_z \frac{\partial S}{\partial z} + i_r \frac{\partial S}{\partial r} \right] \qquad \text{(B-6)}$$

Combining equations (B-1) through (B-6) the terms in (B-2) can be written as:

$$\frac{1}{r}\frac{\partial H_R}{\partial \theta} = \frac{W_a}{r}\left[\frac{\partial W_a}{\partial \theta} - \frac{\partial (rW_u)}{\partial z} \right] - \frac{W_r}{r} \cdot \left[\frac{\partial (rW_u)}{\partial r} - \frac{\partial W_r}{\partial \theta} \right] - 2\omega W_r + \frac{T}{r}\frac{\partial S}{\partial \theta} \qquad \text{(B-7)}$$

$$\frac{\partial H_R}{\partial z} = W_r\left[\frac{\partial W_r}{\partial z} - \frac{\partial W_a}{\partial r} \right] - \frac{W_u}{r}\left[\frac{\partial W_a}{\partial \theta} - \frac{\partial (rW_u)}{\partial z} \right] + T\frac{\partial S}{\partial z} \qquad \text{(B-8)}$$

$$\frac{\partial H_R}{\partial r} = \frac{W_u}{r}\left[\frac{\partial (rW_u)}{\partial r} - \frac{\partial W_r}{\partial \theta} \right] - W_a\left[\frac{\partial W_r}{\partial z} - \frac{\partial W_a}{\partial r} \right] + 2\omega W_u + T\frac{\partial S}{\partial r} \qquad \text{(B-9)}$$

Since the flow has been assumed to be axisymmetric, all derivatives with respect to θ are zero. Thus, Equations (B-7), (B-8) and (B-9) reduce to, respectively:

$$0 = -\frac{W_a}{r}\frac{\partial(rW_u)}{\partial z} - \frac{W_r}{r}\frac{\partial(rW_u)}{\partial r} - 2\omega W_r \qquad \text{(B-10)}$$

$$\frac{\partial H_R}{\partial z} = W_r\frac{\partial W_r}{\partial z} - W_r\frac{\partial W_a}{\partial r} + \frac{W_u}{r}\cdot\frac{\partial(rW_u)}{\partial z} + T\cdot\frac{\partial s}{\partial z} \qquad \text{(B-11)}$$

$$\frac{\partial H_R}{\partial r} = \frac{W_u}{r}\frac{\partial(rW_u)}{\partial r} - W_a\frac{\partial W_r}{\partial z} + W_a\frac{\partial W_a}{\partial r} + 2\omega W_u + T\frac{\partial s}{\partial r} \qquad \text{(B-12)}$$

Equation (B-10) may be written as

$$\frac{\partial(rW_u)}{\partial z} = -\frac{W_r}{W_a}\frac{\partial(rW_u)}{\partial r} - 2\omega r\frac{W_r}{W_a} \qquad \text{(B-13)}$$

Substituting into equation (B-11),

$$\frac{\partial H_R}{\partial z} = -\frac{W_u}{r}\frac{W_r}{W_a}\frac{\partial(rW_u)}{\partial r} + W_r\frac{\partial W_r}{\partial z} - W_r\frac{\partial W_a}{\partial r} - 2\omega\frac{W_u W_r}{W_a} - T\frac{\partial s}{\partial z} \qquad \text{(B-14)}$$

Multiplying equation (B-9) by Wr and Equation (B-14) by Wa results in

$$W_r \frac{\partial H_R}{\partial r} = \frac{W_u W_r}{r} \frac{\partial (r W_u)}{\partial r} - W_a W_r \frac{\partial W_r}{\partial z} +$$

$$W_a W_r \frac{\partial W_a}{\partial r} + 2\omega W_u W_r + W_r T \frac{\partial S}{\partial r} \qquad \text{(B-15)}$$

and

$$W_a \frac{\partial H_R}{\partial z} = - \frac{W_u W_r}{r} \frac{\partial (r W_u)}{\partial r} + W_a W_r \frac{\partial W_r}{\partial z} -$$

$$W_a W_r \frac{\partial W_a}{\partial r} - 2\omega W_u W_r + W_a T \frac{\partial S}{\partial z}$$

$$\text{(B-16)}$$

Adding these two equations yields

$$W_r \frac{\partial H_R}{\partial r} + W_a \frac{\partial H_R}{\partial z} = T \left[W_r \frac{\partial S}{\partial r} + W_a \frac{\partial S}{\partial z} \right] \qquad \text{(B-17)}$$

Since the flow has been assumed to be adiabatic, the total relative enthalpy, H_R, is constant along a streamline. Thus,

$$\nabla H_R = 0 = W_a \frac{\partial H_R}{\partial z} + W_r \frac{\partial H_R}{\partial r} \qquad \text{(B-18)}$$

and re-arranging,

$$\frac{\partial H_R}{\partial z} = - \frac{W_r}{W_a} \frac{\partial H_R}{\partial r} \qquad \text{(B-19)}$$

From equation (B-19), eq. (B-17) can be written as

$$\frac{\partial S}{\partial z} = - \frac{W_r}{W_a} \frac{\partial S}{\partial r} \qquad \text{(B-20)}$$

Substituting Eq.s (B-19) and (B-20) into equation (B-15) gives

$$-\frac{W_r}{W_a}\frac{\partial H_R}{\partial r} = -\frac{W_u}{r}\frac{W_r}{W_a}\frac{\partial (rW_u)}{\partial r} + W_r\frac{\partial W_r}{\partial z} - W_r\frac{\partial W_a}{\partial r} - 2\omega\frac{W_u W_r}{W_a} - \frac{W_r}{W_a}T\frac{\partial s}{\partial r} \qquad \text{(B-21)}$$

Multiplying Equation (B-21) by $\frac{-W_a}{W_R}$ yields

$$\frac{\partial H_R}{\partial r} = \frac{W_u}{r}\frac{\partial (rW_u)}{\partial r} - W_a\frac{\partial W_r}{\partial z} + W_a\frac{\partial W_a}{\partial r} + 2\omega W_u + T\frac{\partial s}{\partial r} \qquad \text{(B-22)}$$

This expression is identical to equation (B-21) and is the equation which must be solved. It must be put into a form which can be solved by the computer. Re-writing equation (B-22) given that

$$W_a\frac{\partial W_a}{\partial r} = \frac{1}{2}\frac{\partial (W_a^2)}{\partial r}$$

yields

$$\frac{\partial (W_a^2)}{\partial r} - 2W_a\frac{\partial W_r}{\partial z} + \frac{2W_u}{r}\frac{\partial (rW_u)}{\partial r} + 4\omega W_u - 2\frac{\partial H_R}{\partial r} + 2T\frac{\partial s}{\partial r} = 0 \qquad \text{(B-23)}$$

The relative enthalpy can be written

$$H_R = h_1 + \frac{W_1^2}{2g_cJ} - \frac{U_1^2}{2g_cJ} = h_2 + \frac{W_2^2}{2g_cJ} - \frac{U_2^2}{2g_cJ} \qquad \text{(B-24)}$$

The equivalent enthalpy, defined in ref. [1] is

$$H_E = h_1 + \frac{W_1^2}{2g_cJ} + \frac{U_2^2 - U_1^2}{2g_cJ} \tag{B-25}$$

Hence, the relative enthalpy can be written as

$$H_R = H_E - \frac{U_2^2}{2} \tag{B-26}$$

Also, the turbine outlet static temperature can be written as

$$T_2 = \frac{H_E}{C_p} - \frac{W_2^2}{2c_p} \tag{B-27}$$

Substituting Eq. (B-26) and Eq. (B-27) into Eq. (B-23) and applying Eq. (B-21) to the rotor exit, gives

$$\frac{\partial (W_a^2)}{\partial r_2} - 2W_{a_2}\frac{\partial W_{r_2}}{\partial z} + 2\frac{W_{u_2}}{r_2}\frac{\partial (r_2 W_{u_2})}{\partial r_2} + 4\omega W_{u_2} - 2\frac{\partial}{\partial r_2}\left[H_E - \frac{U_2^2}{2}\right] + 2\left[\frac{H_E}{C_p} - \frac{W_2^2}{2C_p}\right]\frac{\partial S_2}{\partial r_2} = 0 \tag{B-28}$$

Given the relationships:

$$\mathrm{TAN}^2\lambda = \frac{W_r^2}{W_a^2}$$

and
$$1 + \mathrm{TAN}^2\lambda = \frac{1}{\cos^2\lambda}$$

Equation (B-28) can be written as

$$\frac{\partial(W_{a_2}^2)}{\partial r_2} - 2W_{a_2}\frac{\partial W_{r_2}}{\partial z} - \frac{W_{a_2}^2}{C_p\cos^2\lambda_2}\cdot\frac{\partial S_2}{\partial r_2} + 2\cdot \frac{W_{u_2}}{r_2}\cdot\frac{\partial(r_2 W_{u_2})}{\partial r_2} + 4\omega W_{u_2} - 2\frac{\partial H_E}{\partial r_2} + \frac{\partial(U_2^2)}{\partial r_2} + \frac{1}{C_p}\left[2H_E - W_{u_2}^2\right]\frac{\partial S_2}{\partial r_2} \qquad \text{(B-29)}$$

and substituting $\frac{\partial(U_2^2)}{\partial r_2} = 2\omega^2 r_2$ into equation (B-29) gives

$$\frac{\partial(W_{a_2}^2)}{\partial r_2} - 2W_{a_2}\frac{\partial W_{r_2}}{\partial z} - \frac{W_{a_2}^2}{C_p\cos^2\lambda_2}\,\frac{\partial S_2}{\partial r_2} - 2\,\frac{W_{u_2}}{r_2}\,\frac{\partial(r_2 W_{u_2})}{\partial r_2} + 4\omega W_{u_2} - 2\frac{\partial H_E}{\partial r_2} + 2\omega^2 r_2 + \frac{1}{C_p}\left[2H_E - W_{u_2}^2\right]\frac{\partial S_2}{\partial r_2} \qquad \text{(B-30)}$$

Multiplying Eq. (B-30) by $(\frac{r_m}{W_{a_m}^2})$ results in the dimensionless form of Equation (B-29):

$$\frac{r_{2m}}{Wa_{2m}^2}\frac{\partial(Wa_2^2)}{\partial r_2} - 2\frac{Wa_2}{Wa_{2m}^2}\frac{Wa_2}{Wa_2} r_{2m}\frac{\partial(W_{r_2})}{\partial z} -$$

$$\frac{Wa_2^2\, r_{2m}}{Wa_{2m}^2\, c_p \cos^2\lambda_2}\frac{\partial S_2}{\partial r_2} + 2\frac{Wu_2 Wa_2 r_{2m}}{Wa_{2m} Wa_2 r_2}\cdot\frac{\partial\left[\frac{r_2 Wu_2 Wa_2}{r_{2m} Wa_{2m} Wa_2}\right]}{\partial(r_2/r_{2m})}$$

$$+4\frac{\omega r_{2m} Wu_2 Wa_2}{Wa_{2m}^2\, Wa_2} - 2\frac{r_{2m}}{Wa_{2m}^2}\frac{\partial H_E}{\partial r_2} + \frac{2\omega^2 r_2 r_{2m}}{Wa_{2m}^2} +$$

$$\frac{r_{2m}}{C_p}\left[\frac{\partial H_E}{Wa_{2m}^2} - \frac{Wu_2^2\, Wa_2^2}{Wa_{2m}^2\, Wa_2^2}\right]\frac{\partial S_2}{\partial r_2} \tag{B-31}$$

Introducing the non-dimensional quantities

$$Y = \frac{Wa}{Wa_m} \tag{B-32}$$

$$X = \frac{r}{r_m} \tag{B-33}$$

$$S^* = \frac{S}{c_p} \tag{B-34}$$

Equation (B-31) is written as

$$\frac{\partial (Y^2)}{\partial X} - 2\,\frac{Y^2}{W_a}\,r_m\,\frac{\partial W_r}{\partial z} - \frac{Y^2}{\cos^2\lambda}\,\frac{\partial s^*}{\partial X} + 2Y\,\frac{\tan\beta}{X}\,\frac{\partial (XY\tan\beta)}{\partial X} + 4\,\frac{U_m Y \tan\beta}{W_{a_m}} - \frac{2}{W_{a_m}^2}\,\frac{\partial H_E}{\partial X} + 2\,\frac{U_m U_z}{W_{a_m}^2} + \left[\frac{2H_E}{W_{a_m}^2} - Y^2\tan^2\beta\right]\frac{\partial s^*}{\partial X} = 0 \qquad \text{(B-35)}$$

The fourth term of Eq. (B-35) is

$$2Y\,\frac{\tan\beta}{X}\,\frac{\partial (XY\tan\beta)}{\partial X} = 2Y\,\frac{\tan\beta}{X}\left[XY\,\frac{\partial \tan\beta}{\partial X} + X\tan\beta\,\frac{\partial Y}{\partial X} + Y\tan\beta\,\frac{\partial X}{\partial X}\right]$$

$$= 2Y^2\tan\beta\,\frac{\partial \tan\beta}{\partial X} + 2Y\tan^2\beta\,\frac{\partial Y}{\partial X} + 2\,\frac{Y^2}{X}\tan^2\beta$$

also, $$\frac{\partial \,\mathrm{TAN}\,\beta}{\partial X} = \frac{1}{\cos^2\beta}\,\frac{\partial \beta}{\partial X}$$

and $$2Y\,\mathrm{TAN}^2\beta\,\frac{\partial Y}{\partial X} = \mathrm{TAN}^2\beta\,\frac{\partial (Y^2)}{\partial X}$$

Therefore, equation (B-35) can be written

$$\frac{\partial (Y^2)}{\partial X}\left(1+\mathrm{TAN}^2\beta\right) - 2\,\frac{Y^2}{W_a}\,r_m\,\frac{\partial W_r}{\partial z} - \frac{Y^2}{\cos^2\lambda}\,\frac{\partial s^*}{\partial X} +$$

$$2Y^2\,\frac{\mathrm{TAN}\,\beta}{\cos^2\beta}\,\frac{\partial \beta}{\partial X} + 2\,\frac{Y^2}{X}\,\mathrm{TAN}^2\beta + \frac{4U_m Y\,\mathrm{TAN}\,\beta}{W_{a_m}} -$$

$$\frac{2}{W_{a_m}^2}\,\frac{\partial H_E}{\partial X} + 2\,\frac{U_m U_z}{W_{a_m}^2} + \left[\frac{2H_E}{W_{a_m}^2} - Y^2\,\mathrm{TAN}^2\beta\right]\frac{\partial s^*}{\partial X}$$

(B-36)

Multiplying Eq. (B-36) by ($\dfrac{\cos^2\beta}{Y^2}$) and observing that
$\left(1 + \mathrm{TAN}^2\beta = \dfrac{1}{\cos^2\beta}\right)$,

$$\frac{1}{Y^2}\,\frac{\partial (Y^2)}{\partial X} + \cos^2\beta\left[-\frac{2r_m}{W_a}\cdot\frac{\partial W_r}{\partial z} - \frac{1}{\cos^2\lambda}\,\frac{\partial s^*}{\partial X}\right] +$$

$$2\,\mathrm{TAN}\,\beta\,\frac{\partial \beta}{\partial X} + \frac{2}{X}\,\sin^2\beta + \frac{4U_m \sin\beta\cos\beta}{W_{a_m} Y} + \frac{2U_m U_2\cos^2\beta}{W_{a_m}^2 Y^2}$$

$$-\,\frac{2\cos^2\beta}{W_{a_m}^2}\,\frac{\partial H_E}{\partial X} + \left[\frac{2H_E\cos^2\beta}{W_{a_m}^2 Y^2} - \sin^2\beta\right]\frac{\partial s^*}{\partial Y} = 0$$

(B-37)

To account for streamline curvature the following terms are introduced:

$$\cos^2 \lambda = \frac{L^2}{L^2 + \left(\frac{\Delta R}{2}\right)^2} \qquad \text{(B-38)}$$

where λ, the angle between the axial and radial components of velocity at a point, is approximated as the average value between two stations.

Also,

$$K \frac{\delta R}{L^2} = - \frac{1}{W_a} \frac{\partial W_r}{\partial z} \qquad \text{(B-39)}$$

where δr is the streamline shift throught the rotor defined as

$$\delta r = r_{\substack{\text{ROTOR}\\ \text{OUTLET}}} - r_{\substack{\text{ROTOR}\\ \text{INLET}}} \qquad \text{(B-40)}$$

Substituting Eqs. (B-38) and (B-39) into (B-37) yields

$$\frac{d(\ln Y^2)}{dX} = -\cos^2\beta \left[-\left(2 K r_m \frac{\delta R}{L^2}\right) - \left(\frac{L^2 + (\Delta R)^2}{L^2}\right) \frac{ds^*}{dX} \right]$$

$$- 2 \tan\beta \frac{d\beta}{dX} - \frac{2}{X} \sin^2\beta - \frac{4 U_m \sin\beta \cos\beta}{W_{a_m} Y} -$$

$$\frac{2 U_m U_a \cos^2\beta}{W_{a_m}^2 Y^2} + \frac{2 \cos^2\beta}{W_{a_m}^2 Y^2} \frac{dHE}{dX} - \left[\frac{2 HE \cos^2\beta}{W_{a_m}^2 Y^2} - \sin^2\beta \right] \frac{ds^*}{dX}$$

(B-41)

To obtain a dimensionless equation, the term

$$C_1 = 2g_c J$$

is introduced into Eq. (B-41) giving

$$\frac{d(\ln Y^2)}{dX} = -\cos^2\beta\left[-\left(K\,\frac{2(\delta r)\,r_m}{L^2}\right)-\left(\frac{L^2+(\Delta R)^2}{L^2}\right)\frac{ds^*}{dX}\right] -$$

$$2\tan\beta\,\frac{d\beta}{dX} - \frac{2}{X}\sin^2\beta - \frac{4U_m\sin\beta\cos\beta}{Wa_m Y} - \frac{2U_m U_2\cos^2\beta}{Wa_m^2\,Y^2} +$$

$$\frac{C_1\cos^2\beta}{Wa_m^2\,Y^2}\,\frac{dHE}{dX} - \left[\frac{C_1 HE\cos^2\beta}{Wa_m^2\,Y^2} - \sin^2\beta\right]\frac{ds^*}{dX}$$

(B-42)

Equation (B-42) is the form of equation of motion used in the computer program.

B-2. EQUATION OF MOTION FOR ABSOLUTE FLOW

The equation of motion for absolute flow

$$\nabla H = \vec{V} \times (\nabla \times \vec{V}) + T\,\nabla S$$

(B-43)

Differs from the equation of motion for relative flow

$$\nabla H_R = \vec{W} \times \left(\nabla \times \vec{W} + 2\vec{\omega}\right) + T\nabla S \tag{B-44}$$

only by the term $\vec{W} \times 2\vec{\omega}$ which is the Coroiolis acceleration. To obtain the programmed form of the equation of motion for the stator, the previous derivation is followed, but with $U = 0$, H_E becomes H, W becomes V, and β becomes α.

B-3 THE AREA RESTRICTION FACTOR Z

The condition at the outlet of a blade row with boundary layers on both sides of the flow channel is shown in Fig. B-1. The flow is considered to be turbulent within the boundary layer while, outside the layer, the velocity of the flow is the theoretical velocity. Assuming a power-law velocity profile, the velocity may be written,

$$\frac{u}{V_{TH}} = \left[\frac{y}{\delta}\right]^{m} \tag{B-45}$$

The mass flow rate exiting the blade row can be expressed as

$$\dot{m} = \rho_{TH} V_{TH} \cos\alpha_d \left[S - \frac{t}{\cos\overset{*}{\alpha}_d} - \frac{\Sigma\delta}{\cos\alpha_d} \right] + \Sigma \int_0^{\delta} u\rho \, dy \tag{B-46}$$

where ρ_{th} and V_{th} represent the ideal conditions for an isentropic expansion through the blade row to the discharge

pressure Pd, which is assumed to be constant across the blade spacing. The discharge angle of the flow leaving the blade row is closely approximated by the expression [Ref. 1]

$$\alpha_d = \cos^{-1}\left[\frac{a}{S - \dfrac{t}{\cos^{*}\alpha_d}}\right] \tag{B-47}$$

Inserting Eq. (B- 47) into (B- 46) and reducing yields

$$\dot{m} = \rho_{TH} V_{TH}\, a\left[1 - \Sigma \frac{\delta}{a}\left(1 - \int_0^1 \frac{\rho}{\rho_{TH}}\,\frac{u}{u_{TH}}\, d\eta\right)\right] \tag{B-48}$$

Assuming a perfect gas

$$\frac{\rho}{\rho_{TH}} = \frac{T_{TH}}{T} = \frac{T_{TO} - (T_{TO} - T_{TH})}{T_{TO} - (T_{TO} - T_{TH})\left(\dfrac{u}{V_{TH}}\right)^2} \tag{B-49}$$

Defining

$$X_E = 1 - \left(\frac{P_d}{P_{TO}}\right)^{\frac{\gamma-1}{\gamma}} \tag{B-50}$$

Equation (B- 49) can be written

$$\frac{\rho}{\rho_{TH}} = \frac{1 - X_E}{1 - X_E\left(\dfrac{u}{V_{TH}}\right)^2} \tag{B-51}$$

Substituting Eq. (B- 51) into (B- 45) yields

$$\dot{m} = \rho_{TH} V_{TH}\, a\left[1 - \Sigma \frac{\delta}{a}\left(1 - (1 - X_E)\int_0^1 \frac{\eta^m}{1 - X_E\,\eta^{2m}}\, d\eta\right)\right] \tag{B-52}$$

Using the displacement thickness given by

$$\delta^* = \delta \cdot \left[1 - (1-X_E) \int_0^1 \frac{\eta^m}{(1-X_E \eta^{2m})} \, d\eta \right] \tag{B-53}$$

the mass flow rate can be written as

$$\dot{m} = \rho_{TH} V_{TH} \, a \left[1 - \frac{\Sigma \delta^*}{a} \right] \tag{B-54}$$

The loss coefficient, expressed in terms of average kinetic energy lost is

$$\zeta = \frac{\Delta E}{\dot{m} \left(\frac{V_{TH}^2}{2} \right)} = 1 - \frac{E}{\dot{m} \, \frac{V_{TH}^2}{2}} \tag{B-55}$$

where E is the actual kinetic energy of the flow, given by

$$E = \rho_{TH} V_{TH} (a - \Sigma \delta) \frac{V_{TH}}{2} + \Sigma \int_0^{\delta} \rho u \, \frac{u^2}{2} \, dy \tag{B-56}$$

Substituting Eq. (B-51) into (B-56) gives

$$E = \rho_{TH} \frac{V_{TH}^2}{2} a \left[1 - \Sigma \frac{\delta}{a} \left(1 - (1-X_E) \int_0^1 \frac{\eta^{3m}}{(1-X_E \eta^{2m})} \, d\eta \right) \right] \tag{B-57}$$

The energy thickness is written as

$$\delta^{***} = \delta\left[1 - (1-X_E)\int_0^1 \frac{\eta^{3m}}{(1-X_E\eta^{2m})}\,d\eta\right] \tag{B-58}$$

The loss coefficient can therefore be written as

$$\xi = 1 - \frac{1-\Sigma\frac{\delta^{***}}{a}}{1-\Sigma\frac{\delta^{*}}{a}} \tag{B-59}$$

The area restriction factor Z, is the fraction of the flow area through which the uniform theoretical velocity would produce the actual flow rate, thus

$$Z = \frac{\Sigma\delta^{*}}{a} \tag{B-60}$$

Defining the energy parameter (a form factor) as

$$H^{***} = \frac{\delta^{***}}{\delta^{*}} \tag{B-61}$$

using Equations (B-59) and (B-61), Eq. (B-60) becomes

$$Z = \frac{H^{***}-1}{H^{***}-1+\xi_P} \tag{B-62}$$

where ξp is the profile loss coefficient.

B-4. THE ENERGY PARAMETER, H***

In Equations (B-53) and (B-58) the denominator of the integrand is expanded using the binomial theorem, so that

$$\left(1 - X_E \eta^{2m}\right)^{-1} = 1 + X_E \eta^{2m} + X_E^2 \eta^{4m} + X_E^3 \eta^{6m} + \ldots \tag{B-63}$$

The integral of Equation (B-58) is now written as

$$\int_0^1 \frac{\eta^{3m}\, d\eta}{1 - X_E \eta^{2m}} = \int_0^1 \left[\eta^{3m} + X_E \eta^{5m} + X_E^2 \eta^{7m} + X_E^3 \eta^{9m} + X_E^4 \eta^{11m} + \ldots\right] d\eta \tag{B-64}$$

which, on integration becomes

$$\int_0^1 \frac{\eta^{3m}}{1 - X_E \eta^{2m}}\, d\eta = \frac{1}{3m+1} + \frac{X_E}{5m+1} + \frac{X_E^2}{7m+1} + \frac{X_E^3}{9m+1} + \frac{X_E^4}{11m+1} + \ldots \tag{B-65}$$

Therefore, Equation (B-58) becomes.

$$\frac{\delta^{***}}{\delta} = 1 - \left[\frac{1}{3m+1} + \frac{X_E}{5m+1} + \frac{X_E^2}{7m+1} + \frac{X_E^3}{9m+1} + \frac{X_E^4}{11m+1}\right]\left(1 - X_E\right) \tag{B-66}$$

which can be written as

$$\frac{\delta^{***}}{\delta} = (X_E-1)\left[\frac{1}{X_E-1} + \frac{1}{3m+1} + \frac{X_E}{5m+1} + \frac{X_E^{\,2}}{7m+1} + \frac{X_E^{\,3}}{9m+1} + \frac{X_E^{\,4}}{11m+1}\right] \tag{B-67}$$

In a similar manner,

$$\frac{\delta^{*}}{\delta} = (X_E-1)\left[\frac{1}{X_E-1} + \frac{1}{m+1} + \frac{X_E}{3m+1} + \frac{X_E^{\,2}}{5m+1} + \frac{X_E^{\,3}}{7m+1} + \frac{X_E^{\,4}}{9m+1}\right] \tag{B-68}$$

Substituting Eq. (B-67) and Eq. (B-68) into Eq. (B-61), the equation for H*** used in the computer program is obtained:

$$H^{***} = \frac{\dfrac{1}{X-1} + \dfrac{1}{3m+1} + \dfrac{X_E}{5m+1} + \dfrac{X_E^{\,2}}{7m+1} + \dfrac{X_E^{\,3}}{9m+1} + \dfrac{X_E^{\,4}}{11m+1}}{\dfrac{1}{X_E-1} + \dfrac{1}{m+1} + \dfrac{X_E}{3m+1} + \dfrac{X_E^{\,2}}{5m+1} + \dfrac{X_E^{\,3}}{7m+1} + \dfrac{X_E^{\,4}}{9m+1}} \tag{B-69}$$

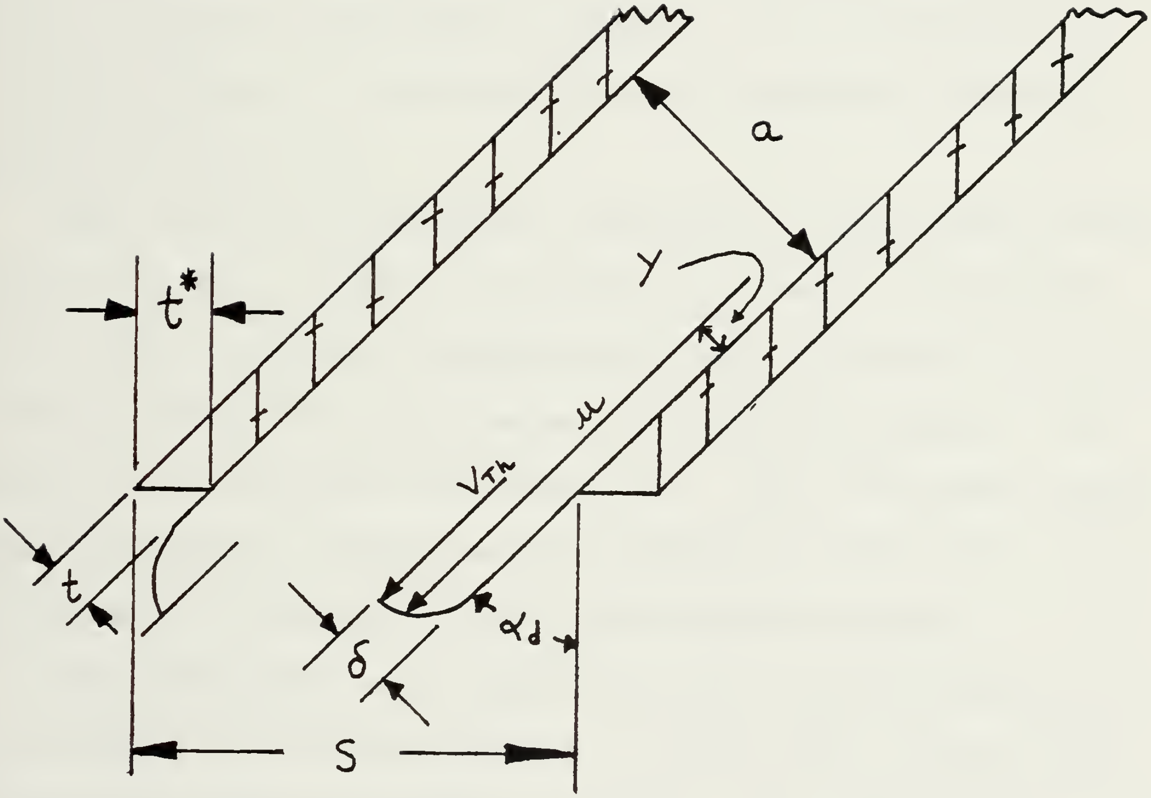


FIGURE B-1: BOUNDARY LAYER EFFECTS AT THE EXIT OF A BLADE ROW

APPENDIX: C

PROGRAM SEGMENTATION ON THE HP-1000

Segmentation allows large programs to be run on the HP-1000. The program is divided by the programmer into a main program and several segments, which are stored on the disc. Each segment and the main program are then compiled and loaded. When the program is executed, the main program and its segments are called into memory individually, and only as they are needed for execution. In this manner, a program can run in a partition which is smaller than that program's total size.

When the main program has performed all executable statements, the first segment is called into memory by an EXEC call. The system then loads that segment from the disc into a memory block following the end of the main program. The process is illustrated in Figure C-1. Note; the main program plus the largest segment may not together exceed 29 k. Once a segment is in memory it can call another segment.

When executing, any segment can call any subroutine which is attached to the main program. It was this feature which allowed the present program to be run. All subroutines were placed within the main program. In fact, the main program consisted of nineteen subroutines and functions. A segment may not return to the main program. Communication of data

between the main program and the segments is accomplished through a common block.

The four segments of the present program are "MAIN", "SHORT", "PART 2" and "PART 3". The manner in which control is passed from the main program to the first segment and from the first segment to the second is as follows:

```
BLOCK DATA
.
.
.
END
PROGRAM THESS
DIMENSION INAM (3)
DATA INAM  /2HSH, 2HOR, 2HT  /
.
.
.
CALL EXEC (8, INAM)
END
PROGRAM SHORT (5)
DIMENSION INAM (3)
DIMENSION NAME (3)
DATA INAM  /2HSH, 2HOR, 2HT  /
DATA NAME /2HPA, 2HRT, 2H2  /
.
.
.
CALL EXEC (8, NAME)
```

```
END
PROGRAM PART 2 (5)
DIMENSION NAME (3)
DIMENSION NAMR (3)
DATA NAME  /2HPA, 2HRT, 2H2  /
DATA NAMR  /2HPA, 2HRT, 2H3  /
.
.
.
CALL EXEC (8, NAMR)
END
PROGRAM PART 3 (5)
DIMENSION NAME (3)
DIMENSION NAMR (3)
DATA NAME  /2HPA, 2HRT, 2H2  /
DATA NAMR  /2HPA, 2HRT, 2H3  /
.
.
.
END
```

The "(5)" after the program name indicates that it is a program segment. Note the manner in which the program name is put into a data statement using the Hollerith notation.

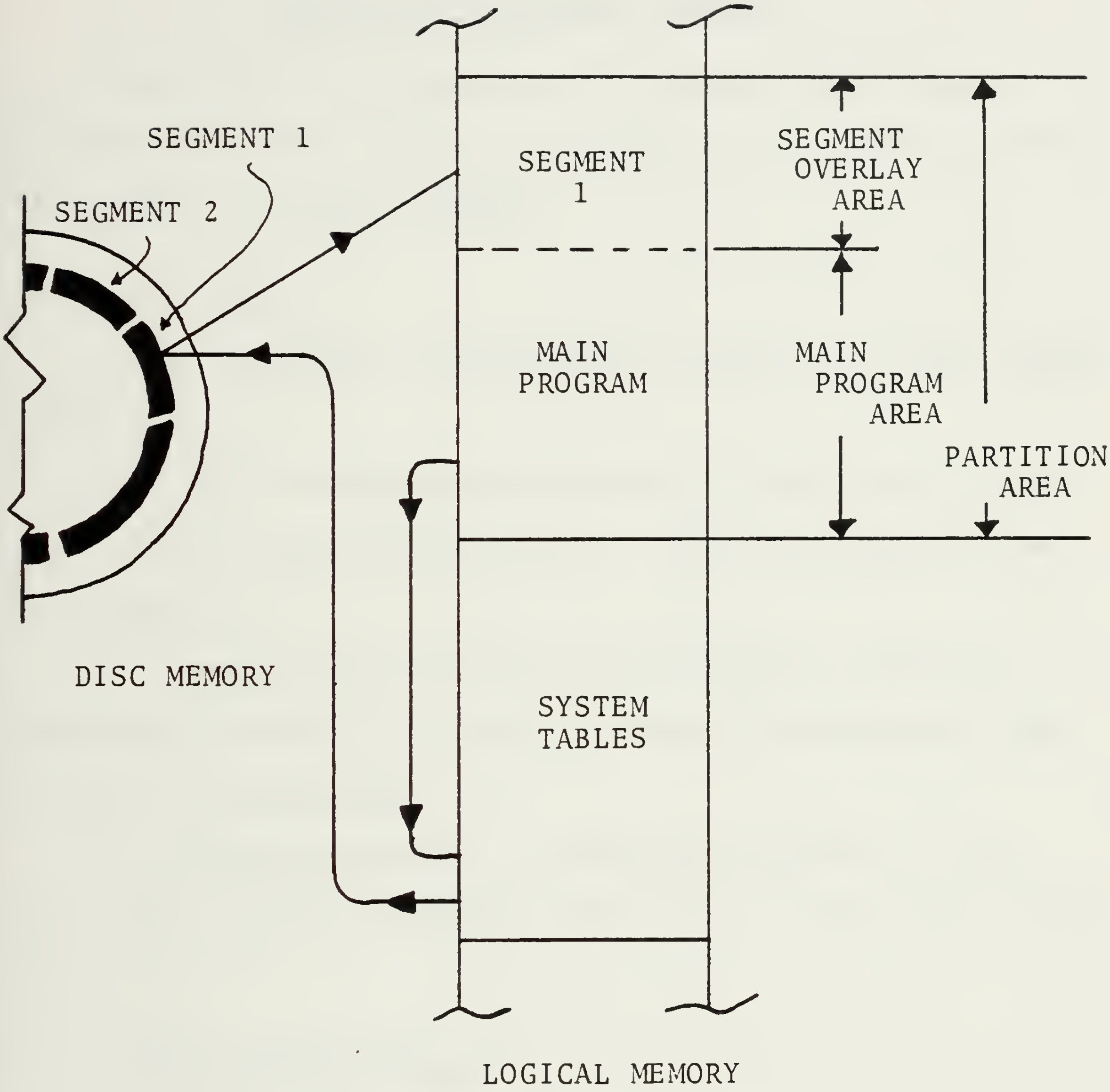


FIGURE C-1: PROGRAM SEGMENTATION-ILLUSTRATION OF THE MAIN PROGRAM CALLING A SEGMENT INTO LOGICAL MEMORY

APPENDIX: D

RUNNING THE COMPUTER PROGRAM

If the reader is unfamiliar with the HP-1000 Computer System, references [11] and [12] should be consulted before attempting to run the program.

D-1. DATA INPUT

Using the editor, input the following data into segment "SHORT".

1. Turbine operating conditions: referring to Table A-III, type in appropriate data in lines 66 through 69 and 74 through 78.

2. Special input data/program control parameters: referring to Tables A-IV and A-V, type in appropriate data in lines 83 through 98.

3. Turbine geometry: referring to Tables A-1 and A-II, type in data for stator and rotor in lines 103 through 186.

D-2 COMPILING THE PROGRAM

1. To compile the main program type:

```
:RU,FTN4,MAIN::25,-,-
```

2. Compile the first segment:

```
:RU,FTN4,SHORT::25,-,-
```

3. Compile the second segment:

```
:RU,FTN4,PART2::25,-,-
```

4. Compile the final segment:

```
:RU,FTN4PART3::25,-,-
```

D-3. LOADING THE PROGRAM

Type

```
: RU, LOADR
```

Tap return key

Will display

```
LOADR:
```

Type

```
OP,LB
```

Will display

```
LOADR:
```

Type

```
:RE,%MAIN::25
```

Will display

```
LOADR:
```

Type

```
:RE,%SHORT::25
```

Will display

```
LOADR:
```

Type

```
:RE,%PART2::25
```

Will display

```
    LOADR:
```

Type

```
    :RE,%PART3::25
```

Will display

```
    LOADR:
```

Type

```
    :END
```

After the end statement, the loader will display that the program is ready for execution.

D-4 RUNNING THE PROGRAM

Type

```
    : RUN, THESS
```

The program will be executed and no further action by the operator is required. The computed pressure ratio of each iteration of the outer loop of the program is displayed on the screen as it is calculated. The operator therefore has some idea where in the iteration process the computer program is executing.

APPENDIX: E

DISCREPANCIES IN MACCHI'S PROGRAM

1. Main program, lines 21 and 22; the value of ICL has not yet been read.

2. Main program, lines 163-166; the Traupel method of calculating gas outlet angles does not take the Mach number into consideration. However, in lines 163-164, the program is attempting to draw a parabola through points which represent outlet angle as a function of Mach number.

3. Main program line 281; the calling of subroutine SLINE is questionable. Parameters are transferred to that subroutine, but many of them have not yet been defined (HE, DHEDX, WPER2, DSDX1). These undefined variables will be set equal to zero by the IBM 360 and 370 computers. Thus, in line 10 of subroutine SLINE, the value of DWDX will be zero and in line 17, division by zero will occur and the execution of the program should cease.

4. Subroutine ROTORI lines 22 and 26; the stator radii are used in the calculation whereas the rotor radii should be used.

5. Subroutine ASOSI, line 107; the correct Fortran code is

```
ZETAPS(I)  = .5 * ZETAS(I)
```

6. Subroutine ALOS2, line 121; the correct Fortran code is

```
ZETAPR(I) = .5 * ZETAPR(I)
```

7. Subroutine ALOS2, lines 123-126; the stator radii are used in the calculation whereas the rotor radii should be used.

8. Subroutine ANGAIN, line 14; the correct Fortran code is

```
AO = ATAN(1. -XCL/H*CH*COS(ANG1)/COS(ANG2)*
     TAN(ANG2) + XCL/H*CL*COS(ANG1)/COS(ANG2)*
     TAN(ANG1)
```

Note: Since reference [2] was published, Professor Macchi's program has been further developed by Professor Macchi under private sponsorship [Ref. 13]. The new code however, is not generally available.

APPENDIX F

COMPUTER OUTPUT

```
                               INPUT PRINTS

                      R1           A1                      R2           A2

                    2.764        .2126                   2.693        .1912
                    2.860        .2215                   2.820        .2030
                    2.956        .2303                   2.947        .2149
                    3.052        .2393                   3.074        .2269
                    3.148        .2481                   3.201        .2388
                    3.243        .2570                   3.329        .2506
                    3.339        .2660                   3.456        .2625
                    3.435        .2749                   3.583        .2745
                    3.531        .2837                   3.710        .2864
                    3.627        .2926                   3.837        .2983

                    NUMBER OF STATOR BLADES =      31.
                    NUMBER OF ROTOR  BLADES =      32.
                    ROTOR TIP CLEARANCE     =    .0100
                    AXIAL DISTANCE L        =      .88
                    CURVATURE FACTOR K      =     5.00

                              BLADING GEOMETRY


               C          E          T          TE         TN         AL         R

            1.0030     2.8065      .2252      .0300      .0186     1.0880     2.7640
  STATOR    1.0030     2.8065      .2252      .0300      .0186     1.0880     3.1955
            1.0030     2.8065      .2252      .0300      .0186     1.0880     3.6270

            1.0030     2.4500      .2252      .0300      .0186     1.0880     2.6930
  ROTOR     1.0030     2.4500      .2252      .0300      .0186     1.0880     3.2650
            1.0030     2.4500      .2252      .0300      .0186     1.0880     3.8370

                 ALL DIMENSIONS INDICATED IN THIS TABLE ARE IN INCHES


                 CORRELATION SYSTEM   ICOR =    4
                                      IAT  =    0
                                      IAN  =    2
                                      ICOZ =    6
                                      IINC =    1
                                      ICL  =    0
                                      ICON =    3
 GAS PROPERTIES        CP        MOLECULAR MASS      GAMM      VISCOSITY (1)    VISCOSITY (2)
                   (BTU/LB F)                                  (LBM /SEC FT)    (LBM /SEC FT)

                     .240          28.970            1.400       .130E-04         .120E-04
```

```
                            SET     PAGE      RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                          NUMBER   NUMBER            PRESSURE RATIO   PRESSURE     TEMPERATURE
                            1        1      5000.0       1.400          20.580        545.50


                                                         STATOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM      BLADE        LOSS         ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING                EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

           (IN)                (IN)     (IN)
  1        2.764       .865   0.0000    .2126     1.1015         .8980        .1020         .1020        0.0000
  2        3.003       .940   0.0000    .2347     1.0468         .8935        .1065         .1065         .2501
  3        3.195      1.000    .0290    .2526     1.0000         .8099        .1101         .1101         .4790
  4        3.432      1.074   0.0000    .2745      .9407         .8871        .1129         .1129         .7609
  5        3.627      1.135   0.0000    .2926      .8916         .8847        .1153         .1153        1.0000


                     ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

  1     332.90       -13.35       735.38        807.33        332.90      -13.35       614.78        699.25        120.60
  2     316.36         3.01       691.09        760.06        316.36        3.01       560.05        643.23        131.03
  3     295.48         6.91       654.34        720.80        295.48        6.91       514.91        593.71        139.43
  4     284.29        24.69       610.59        673.98        284.29       24.69       460.86        542.05        149.73
  5     269.47        31.97       574.92        635.75        269.47       31.97       416.67        497.24        158.26


              MACH NUMBER               FLOW ANGLE             TEMPERATURE              PRESSURE              PRESSURE
                                          (DEG)                 (DEG. R)                 (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC        TOT/TOT    TOT/STA

  1          .74        .64          65.65      61.57       545.50    491.26       19.691    13.648        1.0452     1.5079
  2          .70        .59          65.41      60.54       545.50    497.43       19.762    14.309        1.0414     1.4382
  3          .66        .54          65.21      60.16       545.50    502.27       19.823    14.848        1.0382     1.3861
  4          .61        .49          65.04      58.33       545.50    507.70       19.905    15.482        1.0339     1.3273
  5          .57        .45          64.89      57.11       545.50    511.07       19.970    15.983        1.0305     1.2876
```

```
                  SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                NUMBER   NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                                (PSI)        (DEG. R)

                   1        2       5000.0       1.400         20.580        545.50


                                                      ROTOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM    RADIAL    BLADE     Y=VA /VAM     BLADE       LOSS         ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

  1        2.693       .825     .0710    .1912       .9734       .7689        .2311        .2311        0.0000
  2        3.020       .925    -.0168    .2218       .9964       .7681        .2320        .2320         .2418
  3        3.265      1.000    -.0405    .2447      1.0000       .7674        .2326        .2326         .4446
  4        3.585      1.098    -.1537    .2747      1.0392       .7711        .2289        .2289         .7358
  5        3.837      1.175    -.2100    .2983      1.0911       .7740        .2260        .2260        1.0000


                  ABSOLUTE VELOCITY (FPS)                            RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL    TANGENTIAL    OVERALL         AXIAL      RADIAL    TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT    COMPONENT   COMPONENT     VELOCITY      COMPONENT  COMPONENT   COMPONENT     VELOCITY       VELOCITY

  1     214.82       -8.62      -399.46       453.64        214.82      -8.62     -516.96       559.89         117.50
  2     219.89        2.09      -373.35       433.29        219.89       2.09     -505.11       550.90         131.77
  3     220.69        5.05      -347.58       411.76        220.69       5.05     -490.05       537.47         142.46
  4     229.35       19.92      -323.13       396.75        229.35      19.92     -479.57       531.96         156.44
  5     240.79       28.57      -313.63       396.43        240.79      28.57     -481.05       538.71         167.42


              MACH NUMBER              FLOW ANGLE           TEMPERATURE             PRESSURE              PRESSURE
                                         (DEG)               (DEG. R)                (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE  RELATIVE      ABSOLUTE  RELATIVE       TOTAL    STATIC       TOTAL    STATIC       TOT/TOT    TOT/STA

  1          .41       .51         -61.73    -67.44        522.93   505.80       16.080   14.311       1.2799     1.4381
  2          .39       .50         -59.51    -66.48        522.24   506.62       16.090   14.467       1.2791     1.4225
  3          .37       .49         -57.59    -65.76        522.08   507.63       16.162   14.650       1.2734     1.4043
  4          .36       .48         -54.64    -64.45        521.87   508.77       16.242   14.859       1.2671     1.3853
  5          .36       .49         -52.49    -63.41        521.62   508.54       16.260   14.877       1.2657     1.3333


STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
 LINE     TEMPERATURE    INLET         PRESSURE
                         PRESSURE        RATIO
           (DEG. R)      (PSI
  1         531.89        18.024         1.3
  2         531.87        18.088         1.3
  3         531.67        18.119         1.2
  4         532.32        18.272         1.2
  5         532.69        18.376         1.2
```

```
   SET     PAGE       RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
 NUMBER   NUMBER              PRESSURE RATIO   PRESSURE       TEMPERATURE
                                                 (PSI)          (DEG. R)

    1        3      5000.0        1.400         20.580          545.50


                          OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO            EFFICIENCY          HEAD       BLADE/JET    THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.4381     1.2799       .4197        .6079     44.4345       .1500         -.1231
  2       1.4225     1.2791       .4451        .6279     36.5720       .1654         -.0296
  3       1.4048     1.2734       .4640        .6436     31.2045       .1790          .0376
  4       1.3850     1.2671       .4875        .6623     25.9802       .1962          .1209
  5       1.3833     1.2657       .4944        .6724     23.1752       .2077          .2130


                                  MASS AVERAGED QUANTITIES


                            HORSE POWER =       20.27    (HP)
                            MOMENT      =       21.29    (FT-LB)
                            FLOW RATE   =        2.55    (LB/SEC)


                     REFERRED  RPM         =   4874.22
                     REFERRED HORSE POWER  =     14.12   (HP)
                     REFERRED MOMENT       =     15.21   (FT-LB)
                     REFERRED FLOW RATE    =      1.07   (LB/SEC)


                  TOTAL/STATIC EFFICIENCY =       .4634
                  TOTAL/TOTAL  EFFICIENCY=        .6435
               TOTAL/STATIC PRESSURE RATIO =     1.4058
               TOTAL/TOTAL  PRESSURE RATIO =     1.2731


              HEAD COEFFICIENT               =   31.8904
              BLADE/JET SPEED RATIO          =     .1771
              THEORETICAL DEGREE OF REACTION=      .0435
              MACH NUMBER AT STATION 0       =     .1856
```

```
                   SET      PAGE        RPM       TOTAL/STATIC      INLET TOTAL   INLET TOTAL
                 NUMBER    NUMBER                PRESSURE RATIO    PRESSURE      TEMPERATURE
                    1         1       10000.0         1.400          20.580          545.50


                                                     STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM       BLADE         LOSS          ZETA*          FLOW RATE
 LINE    POSITION               SHIFT   OPENING                   EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                  (IN)     (IN)
   1       2.764       .865    0.0000     .2126       1.0991         .8889         .1111          .1111          0.0000
   2       3.003       .940    0.0000     .2347       1.0455         .8856         .1144          .1144           .2602
   3       3.195      1.000     .0290     .2526       1.0000         .8829         .1171          .1171           .4813
   4       3.432      1.074    0.0000     .2745        .9430         .8852         .1148          .1148           .7624
   5       3.627      1.135    0.0000     .2926        .8960         .8872         .1128          .1128          1.0000


                   ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL     TANGENTIAL     OVERALL          AXIAL       RADIAL     TANGENTIAL     OVERALL          WHEEL
 LINE COMPONENT      COMPONENT     COMPONENT     VELOCITY      COMPONENT   COMPONENT     COMPONENT     VELOCITY       VELOCITY

   1     291.65        -11.70        644.27        707.30         291.65      -11.70        403.06        497.65         241.21
   2     277.43          2.64        606.06        666.55         277.43        2.64        343.99        441.93         262.07
   3     265.36          6.07        574.53        632.89         265.36        6.07        295.67        397.34         278.86
   4     250.25         21.73        537.47        593.27         250.25       21.73        238.00        346.03         299.47
   5     237.78         28.21        507.31        560.98         237.78       28.21        190.79        306.16         316.52


              MACH NUMBER                 FLOW ANGLE              TEMPERATURE               PRESSURE                  PRESSURE
                                            (DEG)                  (DEG. R)                  (PSI)                     RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE        ABSOLUTE   RELATIVE        TOTAL      STATIC        TOTAL     STATIC          TOT/TOT     TOT/STA

   1          .64        .45           65.65      54.12        545.50      503.87       19.846     15.032           1.0370      1.3691
   2          .60        .40           65.41      51.12        545.50      508.53       19.911     15.575           1.0336      1.3214
   3          .57        .36           65.21      48.10        545.50      512.17       19.965     16.012           1.0308      1.2853
   4          .53        .31           65.04      43.57        545.50      516.21       20.055     16.533           1.0262      1.2448
   5          .50        .27           64.89      38.75        545.50      519.31       20.122     16.939           1.0228      1.2149
```

```
   SET      PAGE        RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
 . NUMBER   NUMBER                PRESSURE RATIO   PRESSURE       TEMPERATURE
                                                     (PSI)         (DEG. R)

    1         2      10000.0         1.400          20.580         545.50


                                         ROTOR EXIT SOLUTION


STREAM   RADIAL      X=R/RM   RADIAL     BLADE     Y=VA /VAM    BLADE        LOSS         ZETA*       FLOW RATE
 LINE    POSITION            SHIFT     OPENING                EFFICIENCY   COEFFICIENT   CONTINUITY   FRACTION

  1       2.693       .825    .0710     .1912       .9837       .8286        .1715        .1715       0.0000
  2       3.020       .925   -.0168     .2218       .9556       .8373        .1628        .1628        .2340
  3       3.265     1.000   -.0405     .2447     1.0000       .8438        .1563        .1563        .4308
  4       3.585     1.098   -.1537     .2747     1.0916       .8515        .1485        .1485        .7242
  5       3.837     1.175   -.2100     .2983     1.1871       .8576        .1425        .1425       1.0000


                 ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM   AXIAL       RADIAL     TANGENTIAL   OVERALL        AXIAL       RADIAL      TANGENTIAL   OVERALL       WHEEL
 LINE  COMPONENT   COMPONENT   COMPONENT    VELOCITY      COMPONENT   COMPONENT    COMPONENT    VELOCITY     VELOCITY

  1     201.32      -8.08      -249.46      320.66        201.32      -8.08       -484.47      524.70       235.01
  2     195.57       1.86      -185.71      269.70        195.57       1.86       -449.25      489.97       263.54
  3     204.66       4.68      -169.51      265.78        204.66       4.68       -454.44      498.42       284.93
  4     223.41      19.40      -154.28      272.20        223.41      19.40       -467.17      518.20       312.88
  5     242.95      28.82      -150.52      287.25        242.95      28.82       -485.36      543.54       334.84


          MACH NUMBER             FLOW ANGLE            TEMPERATURE          PRESSURE             PRESSURE
                                    (DEG)                (DEG. R)             (PSI)                RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE     TOTAL    STATIC     TOTAL    STATIC     TOT/TOT   TOT/STA

  1         .29      .48        -51.10    -67.44      509.88   501.32     15.156   14.284     1.3579    1.4407
  2         .24      .44        -43.52    -66.48      510.92   504.87     15.411   14.781     1.3355    1.3923
  3         .24      .45        -39.64    -65.76      510.80   504.92     15.445   14.832     1.3325    1.3876
  4         .25      .47        -34.63    -64.45      510.68   504.51     15.494   14.849     1.3282    1.3859
  5         .26      .49        -31.78    -63.41      510.39   503.52     15.494   14.777     1.3283    1.3927


STREAM   EQUIVALENT    EQUIVALENT   EQUIV/STATIC
 LINE    TEMPERATURE   INLET         PRESSURE
                       PRESSURE        RATIO
          (DEG. R)     (PSI)
  1       524.23        17.267         1.2
  2       524.85        17.395         1.2
  3       525.59        17.529         1.2
  4       526.86        17.757         1.2
  5       528.11        17.964         1.2
```

```
  SET     PAGE       RPM     TOTAL/STATIC     INLET TOTAL   INLET TOTAL
 NUMBER  NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                (PSI)         (DEG. R)

   1       3    10000.0         1.400          20.580        545.50

              OVERALL TURBINE CHARACTERISTICS

STREAM     PRESSURE RATIO           EFFICIENCY            HEAD       BLADE/JET     THEORETICAL
 LINE    TOT/STA    TOT/TOT     TOT/STA       TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1      1.4407     1.3579       .6591         .7802     11.1627        .2993           .1334
  2      1.3923     1.3355       .7025         .7991      8.6122        .3408           .1518
  3      1.3876     1.3325       .7121         .8080      7.5311        .3644           .2253
  4      1.3859     1.3282       .7170         .8195      6.5076        .3920           .3107
  5      1.3927     1.3283       .7128         .8263      5.9090        .4114           .4008

                           MASS AVERAGED QUANTITIES

                     HORSE POWER =     28.96   (HP)
                     MOMENT      =     15.21   (FT-LB)
                     FLOW RATE   =      2.45   (LB/SEC)

               REFERRED  RPM         =   9748.44
               REFERRED HORSE POWER  =     20.17   (HP)
               REFERRED MOMENT       =     10.86   (FT-LB)
               REFERRED FLOW RATE    =      1.79   (LB/SEC)

             TOTAL/STATIC EFFICIENCY =     .7044
             TOTAL/TOTAL  EFFICIENCY=      .8075
          TOTAL/STATIC PRESSURE RATIO =   1.3956
          TOTAL/TOTAL  PRESSURE RATIO =   1.3348

          HEAD COEFFICIENT            =   7.7967
          BLADE/JET SPEED RATIO       =    .3581
          THEORETICAL DEGREE OF REACTION=  .2407
          MACH NUMBER AT STATION 0    =    .1777
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                 SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                NUMBER  NUMBER             PRESSURE RATIO   PRESSURE      TEMPERATURE
                  1       1     15000.0        1.400         20.580          545.50

                                                          STATOR EXIT SOLUTION

 STREAM    RADIAL      X=R/RM    RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS          ZETA*         FLOW RATE
  LINE    POSITION               SHIFT    OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY      FRACTION

            (IN)                 (IN)      (IN)
   1        2.764       .865    0.0000     .2126      1.0977        .8955         .1045         .1045         0.0000
   2        3.003       .940    0.0000     .2347      1.0453        .8953         .1047         .1047          .2610
   3        3.195      1.000     .0290     .2526      1.0000        .8952         .1048         .1048          .4826
   4        3.432      1.074    0.0000     .2745       .9416        .8948         .1052         .1052          .7635
   5        3.627      1.135    0.0000     .2926       .8928        .8945         .1055         .1055         1.0000

                   ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

 STREAM     AXIAL         RADIAL     TANGENTIAL    OVERALL          AXIAL        RADIAL     TANGENTIAL    OVERALL         WHEEL
  LINE COMPONENT       COMPONENT    COMPONENT     VELOCITY        COMPONENT    COMPONENT    COMPONENT     VELOCITY        VELOCITY

   1      279.79        -11.22       618.08        678.55          279.79       -11.22       256.27        379.59          361.81
   2      266.45          2.53       582.07        640.16          266.45         2.53       108.97        326.67          393.10
   3      254.90          5.83       551.88        607.93          254.90         5.83       133.59        287.84          418.29
   4      240.00         20.84       515.46        568.98          240.00        20.84        66.26        249.85          449.20
   5      227.58         27.00       485.56        536.93          227.58        27.00        10.79        229.43          474.77

              MACH NUMBER                 FLOW ANGLE              TEMPERATURE              PRESSURE                 PRESSURE
                                            (DEG)                  (DEG. R)                 (PSI)                     RATIO
 STREAM
  LINE     ABSOLUTE   RELATIVE        ABSOLUTE  RELATIVE         TOTAL     STATIC        TOTAL     STATIC          TOT/TOT     TOT/STA

   1           .61        .34           65.65     42.49          545.50     507.19        19.952     15.463          1.0315      1.3309
   2           .58        .29           65.41     35.35          545.50     511.40        20.024     15.975          1.0278      1.2883
   3           .55        .26           65.21     27.66          545.50     514.75        20.081     16.390          1.0249      1.2557
   4           .51        .22           65.04     15.43          545.50     518.56        20.144     16.872          1.0217      1.2198
   5           .48        .20           64.89      2.71          545.50     521.51        20.192     17.251          1.0192      1.1930
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              SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
            NUMBER   NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                             (PSI)        (DEG. R)

              1         2      15000.0        1.400          20.580        545.50


                                         ROTOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS        ZETA*       FLOW RATE
 LINE    POSITION               SHIFT    OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1       2.693          .825    .0710    .1912       .9944      .8722       .1279       .1279       0.0000
  2       3.020          .925   -.0168    .2218       .9132      .8785       .1216       .1216        .2253
  3       3.265         1.000   -.0405    .2447      1.0000      .8832       .1169       .1169        .4152
  4       3.585         1.098   -.1537    .2747      1.1537      .8737       .1263       .1263        .7112
  5       3.837         1.175   -.2100    .2983      1.3031      .8663       .1337       .1337       1.0000

                 ABSOLUTE VELOCITY (FPS)                          RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL       AXIAL       RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY    COMPONENT   COMPONENT    COMPONENT     VELOCITY     VELOCITY

  1     192.13        -7.71       -109.84       221.44      192.13       -7.71       -462.35      500.74       352.51
  2     176.44         1.68        -10.00       176.73      176.44        1.68       -405.30      442.05       395.31
  3     193.21         4.42         -1.64       193.27      193.21        4.42       -429.03      470.55       427.39
  4     222.92        19.36          3.20       223.78      222.92       19.36       -466.13      517.05       469.33
  5     251.77        29.87          -.72       253.54      251.77       29.87       -502.98      563.27       502.26

           MACH NUMBER             FLOW ANGLE            TEMPERATURE           PRESSURE              PRESSURE
                                     (DEG)                 (DEG. R)              (PSI)                RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE       TOTAL    STATIC      TOTAL    STATIC      TOT/TOT    TOT/STA

  1        .20       .46        -29.76    -67.44       501.84    497.76     14.582    14.171      1.4113     1.4523
  2        .16       .40         -3.24    -66.48       506.76    504.16     15.233    14.961      1.3510     1.3756
  3        .18       .43          -.49    -65.76       506.97    503.86     15.277    14.952      1.3471     1.3764
  4        .20       .47           .82    -64.45       507.21    503.05     15.268    14.833      1.3479     1.3874
  5        .23       .51          -.16    -63.41       507.07    501.72     15.197    14.643      1.3542     1.4054


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1       518.62       16.718        1.2
  2       520.42       16.983        1.1
  3       522.28       17.245        1.2
  4       525.29       17.651        1.2
  5       528.13       18.029        1.2
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                    SET    PAGE      RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                   NUMBER  NUMBER             PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                (PSI)         (DEG. R)

                     1       3     15000.0        1.400         20.580         545.50


                              OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO           EFFICIENCY             HEAD        BLADE/JET      THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1      1.4523     1.4113       .7916        .8538       5.0637         .4444            .2243
   2      1.3756     1.3510       .8156        .8622       3.6937         .5203            .1981
   3      1.3764     1.3471       .8098        .8657       3.2684         .5531            .2781
   4      1.3874     1.3479       .7859        .8584       2.9014         .5871            .3821
   5      1.4054     1.3542       .7602        .8488       2.6948         .6092            .4694


                                        MASS AVERAGED QUANTITIES


                                       HORSE POWER =        31.71    (HP)
                                       MOMENT      =        11.10    (FT-LB)
                                       FLOW RATE   =         2.39    (LB/SEC)

                              REFERRED  RPM         =  14622.66
                              REFERRED HORSE POWER =        22.08    (HP)
                              REFERRED MOMENT      =         7.93    (FT-LB)
                              REFERRED FLOW RATE   =         1.75    (LB/SEC)

                          TOTAL/STATIC EFFICIENCY =        .7968
                          TOTAL/TOTAL  EFFICIENCY=         .8594
                       TOTAL/STATIC PRESSURE RATIO =      1.3921
                       TOTAL/TOTAL  PRESSURE RATIO =      1.3572

                    HEAD COEFFICIENT                =     3.4357
                    BLADE/JET SPEED RATIO           =      .5395
                    THEORETICAL DEGREE OF REACTION=        .3013
                    MACH NUMBER AT STATION 0        =      .1735
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              SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
            NUMBER   NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
               1        1     20000.0         1.400         20.580          545.50

                                                   STATOR EXIT SOLUTION

 STREAM    RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE       LOSS         ZETA*        FLOW RATE
  LINE    POSITION             SHIFT    OPENING                 EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

            (IN)               (IN)     (IN)
    1       2.764       .865   0.0000    .2126     1.1027       .9123        .0877        .0877        0.0000
    2       3.003       .940   0.0000    .2347     1.0473       .9091        .0909        .0909         .2613
    3       3.195      1.000    .0290    .2526     1.0000       .9065        .0935        .0935         .4829
    4       3.432      1.074   0.0000    .2745      .9400       .9051        .0949        .0949         .7637
    5       3.627      1.135   0.0000    .2926      .8903       .9040        .0960        .0960        1.0000

                     ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

 STREAM     AXIAL       RADIAL    TANGENTIAL    OVERALL        AXIAL      RADIAL    TANGENTIAL    OVERALL      WHEEL
  LINE COMPONENT     COMPONENT    COMPONENT    VELOCITY     COMPONENT  COMPONENT   COMPONENT    VELOCITY     VELOCITY

    1     291.10       -11.68      643.06      705.98        291.10     -11.68      160.65      332.69       482.41
    2     276.49         2.63      604.00      664.29        276.49       2.63       79.86      287.81       524.14
    3     241.95         6.04      571.59      629.64        241.95       6.04       13.87      242.42       557.72
    4     248.16        21.55      532.98      588.31        248.16      21.55      -65.96      257.68       598.94
    5     235.05        27.89      501.49      554.54        235.05      27.89     -131.54      270.79       633.03

              MACH NUMBER              FLOW ANGLE           TEMPERATURE            PRESSURE               PRESSURE
                                         (DEG)               (DEG. R)               (PSI)                  RATIO
 STREAM
  LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE      TOTAL     STATIC      TOTAL     STATIC      TOT/TOT    TOT/STA

    1          .64        .30         65.65      28.89       545.50    504.03      20.016    15.177      1.0282     1.3560
    2          .60        .26         65.41      16.11       545.50    508.70      20.065    15.722      1.0257     1.3070
    3          .57        .22         65.21       3.28       545.50    512.51      20.106    16.162      1.0236     1.2733
    4          .53        .23         65.04     -14.89       545.50    516.70      20.162    16.676      1.0207     1.2341
    5          .50        .24         64.89     -29.24       545.50    519.91      20.206    17.079      1.0185     1.2050
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    SET     PAGE       RPM       TOTAL/STATIC     INLET TOTAL   INLET TOTAL
  NUMBER   NUMBER               PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                     (PSI)       (DEG. R)

    1        2      20000.0         1.400           20.580        545.50

                                  ROTOR EXIT SOLUTION

STREAM  RADIAL     X=R/RM  RADIAL    BLADE    Y=VA /VAM   BLADE       LOSS        ZETA*      FLOW RATE
 LINE   POSITION           SHIFT    OPENING             EFFICIENCY COEFFICIENT CONTINUITY   FRACTION

  1      2.693      .825   .0710     .1912    1.0076     .8915       .1085       .1085       0.0000
  2      3.020      .925  -.0168     .2218     .8705     .8756       .1244       .1244        .2140
  3      3.265     1.000  -.0405     .2447    1.0000     .8637       .1364       .1364        .3939
  4      3.585     1.098  -.1537     .2747    1.2350     .8696       .1304       .1304        .6917
  5      3.837     1.175  -.2100     .2983    1.4565     .8743       .1258       .1258       1.0000

              ABSOLUTE VELOCITY (FPS)                          RELATIVE VELOCITY (FPS)

STREAM    AXIAL     RADIAL    TANGENTIAL   OVERALL       AXIAL     RADIAL    TANGENTIAL   OVERALL      WHEEL
 LINE  COMPONENT  COMPONENT   COMPONENT    VELOCITY    COMPONENT  COMPONENT  COMPONENT    VELOCITY    VELOCITY

  1     178.28      -7.15       40.98       183.07      178.28     -7.15      -429.04     464.66      470.02
  2     154.03       1.46      173.25       231.82      154.03      1.46      -353.82     385.90      527.07
  3     176.94       4.05      176.95       250.27      176.94      4.05      -392.90     430.92      569.85
  4     218.53      18.98      168.82       276.79      218.53     18.98      -456.95     506.87      625.77
  5     257.72      30.58      154.81       302.20      257.72     30.58      -514.88     576.59      669.68

           MACH NUMBER           FLOW ANGLE           TEMPERATURE            PRESSURE            PRESSURE
                                   (DEG)               (DEG. R)              (PSI)                RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE   ABSOLUTE  RELATIVE     TOTAL    STATIC      TOTAL    STATIC     TOT/TOT   TOT/STA

  1         .17       .43      12.95     -67.44     497.08    494.29     14.234    13.957     1.4458    1.4745
  2         .21       .35      48.36     -66.48     508.01    503.54     15.448    14.978     1.3322    1.3741
  3         .23       .39      45.00     -65.76     509.23    503.09     15.536    14.890     1.3247    1.3821
  4         .25       .46      37.69     -64.45     509.96    503.58     15.574    14.903     1.3214    1.3809
  5         .28       .52      30.99     -63.41     509.92    502.32     15.519    14.725     1.3261    1.3977

STREAM  EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE   TEMPERATURE    INLET       PRESSURE
                      PRESSURE       RATIO
         (DEG. R)      (PSI
  1       512.26      16.062          1.2
  2       515.93      16.509          1.1
  3       518.54      16.837          1.1
  4       524.96      17.628          1.2
  5       529.99      18.265          1.2
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                       SET    PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                      NUMBER NUMBER             PRESSURE RATIO  PRESSURE      TEMPERATURE
                                                                  (PSI)        (DEG. R)

                        1      3    20000.0         1.400        20.580         545.50


                                      OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO            EFFICIENCY             HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA   TOT/TOT      TOT/STA      TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.4745    1.4458        .8453        .8880       2.9583        .5814           .2065
  2       1.3741    1.3322        .7919        .8735       2.0709        .6949           .1468
  3       1.3821    1.3247        .7529        .8615       1.8612        .7330           .2446
  4       1.3809    1.3214        .7398        .8514       1.6096        .7882           .3378
  5       1.3977    1.3261        .7150        .8419       1.4923        .8186           .4311


                                          MASS AVERAGED QUANTITIES

                                   HORSE POWER =      28.63   (HP)
                                   MOMENT      =       7.52   (FT-LB)
                                   FLOW RATE   =       2.25   (LB/SEC)

                              REFERRED  RPM         =  19496.88
                              REFERRED HORSE POWER  =     19.94   (HP)
                              REFERRED MOMENT       =      5.37   (FT-LB)
                              REFERRED FLOW RATE    =      1.65   (LB/SEC)

                         TOTAL/STATIC EFFICIENCY =       .7662
                          TOTAL/TOTAL   EFFICIENCY=      .8628
                      TOTAL/STATIC PRESSURE RATIO =     1.3933
                      TOTAL/TOTAL  PRESSURE RATIO =     1.3411

                    HEAD COEFFICIENT                =   1.9418
                    BLADE/JET SPEED RATIO           =    .7176
                    THEORETICAL DEGREE OF REACTION=      .2620
                    MACH NUMBER AT STATION 0        =    .1629
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                  SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                 NUMBER   NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                   1        1     25000.0          1.400          20.580          545.50


                                                    STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS          ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                  (IN)      (IN)
  1       2.764        .865    0.0000     .2126      1.1005         .9045         .0955         .0955         0.0000
  2       3.003        .940    0.0000     .2347      1.0465         .9026         .0974         .0974          .2612
  3       3.195       1.000     .0290     .2526      1.0000         .9011         .0989         .0989          .4829
  4       3.432       1.074    0.0000     .2745       .9405         .8997         .1003         .1003          .7637
  5       3.627       1.135    0.0000     .2926       .8912         .8986         .1014         .1014         1.0000


                     ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY       COMPONENT    COMPONENT   COMPONENT     VELOCITY        VELOCITY

  1     285.88        -11.47        631.53       693.32         285.88       -11.47        28.52       287.53         603.01
  2     271.85          2.58        593.87       653.14         271.85         2.58       -61.31       278.69         655.17
  3     263.01          5.94        562.45       619.58         263.01         5.94      -134.70       295.56         697.15
  4     244.34         21.22        524.77       579.25         244.34        21.22      -223.90       332.09         748.67
  5     231.51         27.47        493.94       546.20         231.51        27.47      -297.35       377.85         791.29


               MACH NUMBER                FLOW ANGLE             TEMPERATURE             PRESSURE              PRESSURE
                                            (DEG)                 (DEG. R)                (PSI)                 RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE         ABSOLUTE   RELATIVE        TOTAL      STATIC       TOTAL      STATIC       TOT/TOT      TOT/STA

  1          .63        .26             65.65       5.70         545.50     505.50       19.985     15.309       1.0298       1.3443
  2          .59        .25             65.41     -12.71         545.50     510.00       20.044     15.838       1.0267       1.2994
  3          .56        .27             65.21     -27.12         545.50     513.56       20.092     16.267       1.0243       1.2651
  4          .52        .30             65.04     -42.50         545.50     517.58       20.150     16.766       1.0213       1.2275
  5          .49        .34             64.89     -52.10         545.50     520.68       20.195     17.157       1.0191       1.1995
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   SET      PAGE       RPM     TOTAL/STATIC    INLET TOTAL    INLET TOTAL
  NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                  (PSI)        (DEG. R)

    1         2     25000.0        1.400          20.580         545.50

                                  ROTOR EXIT SOLUTION

STREAM   RADIAL     X=R/RM  RADIAL    BLADE    Y=VA /VAM    BLADE       LOSS         ZETA*       FLOW RATE
 LINE   POSITION             SHIFT   OPENING             EFFICIENCY  COEFFICIENT  CONTINUITY     FRACTION

   1      2.693       .825   .0710    .1912    1.0181      .8812        .1189        .1189        0.0000
   2      3.020       .925  -.0168    .2218     .8317      .8756        .1245        .1245         .2053
   3      3.265      1.000  -.0405    .2447    1.0000      .8714        .1287        .1287         .3807
   4      3.585      1.098  -.1537    .2747    1.2682      .8796        .1205        .1205         .6822
   5      3.837      1.175  -.2100    .2983    1.5106      .8861        .1140        .1140        1.0000

             ABSOLUTE VELOCITY (FPS)                          RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL    TANGENTIAL   OVERALL      AXIAL     RADIAL    TANGENTIAL   OVERALL      WHEEL
 LINE  COMPONENT   COMPONENT   COMPONENT   VELOCITY    COMPONENT  COMPONENT  COMPONENT   VELOCITY    VELOCITY

   1     193.70      -7.77      121.38      228.72      193.70      -7.77     -466.14     504.85      587.52
   2     158.25       1.50      295.33      335.06      158.25       1.50     -363.52     396.47      658.84
   3     190.26       4.35      289.84      346.74      190.26       4.35     -422.47     463.36      712.31
   4     241.28      20.96      277.69      368.46      241.28      20.96     -504.53     559.64      782.21
   5     287.40      34.10      262.93      391.02      287.40      34.10     -574.17     642.99      837.11

          MACH NUMBER           FLOW ANGLE         TEMPERATURE          PRESSURE            PRESSURE
                                  (DEG)             (DEG. R)             (PSI)                RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE   ABSOLUTE  RELATIVE    TOTAL    STATIC     TOTAL    STATIC     TOT/TOT   TOT/STA

   1       .21       .47       32.07    -67.44     493.99   489.64     13.836   13.414     1.4874    1.5342
   2       .30       .36       61.82    -66.48     513.13   503.79     15.973   14.978     1.2885    1.3740
   3       .31       .42       56.72    -65.76     514.60   504.74     16.086   15.032     1.2794    1.3691
   4       .33       .51       49.02    -64.45     516.26   504.97     16.209   15.001     1.2696    1.3719
   5       .36       .58       42.46    -63.41     517.08   504.36     16.238   14.882     1.2674    1.3829

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1       510.85       15.883        1.2
  2       516.87       16.597        1.1
  3       522.60       17.292        1.2
  4       531.03       18.340        1.2
  5       538.76       19.336        1.3
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```
           SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL    INLET TOTAL
          NUMBER  NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                         (PSI)         (DEG. R)

            1       3     25000.0         1.400         20.580         545.50

                         OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO            EFFICIENCY             HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT      TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       1.5342     1.4874       .8204        .8806        2.0751         .6942          .2957
  2       1.3740     1.2885       .6838        .8496        1.3253         .8686          .1693
  3       1.3691     1.2794       .6598        .8332        1.1578         .9294          .2430
  4       1.3719     1.2696       .6205        .8129        1.0102         .9950          .3414
  5       1.3829     1.2674       .5889        .7957         .9261        1.0391          .4275

                                MASS AVERAGED QUANTITIES

                               HORSE POWER =        26.78   (HP)
                               MOMENT      =         5.63   (FT-LB)
                               FLOW RATE   =         2.43   (LB/SEC)

                     REFERRED  RPM         =     24371.10
                     REFERRED HORSE POWER  =        18.64   (HP)
                     REFERRED MOMENT       =         4.02   (FT-LB)
                     REFERRED FLOW RATE    =         1.78   (LB/SEC)

                 TOTAL/STATIC EFFICIENCY   =        .6672
                 TOTAL/TOTAL   EFFICIENCY=          .8335
              TOTAL/STATIC PRESSURE RATIO  =       1.3934
              TOTAL/TOTAL  PRESSURE RATIO  =       1.3037

            HEAD COEFFICIENT               =       1.2485
            BLADE/JET SPEED RATIO          =        .8950
            THEORETICAL DEGREE OF REACTION=         .2788
            MACH NUMBER AT STATION 0       =        .1768
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                                     SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                                    NUMBER   NUMBER               PRESSURE RATIO   PRESSURE       TEMPERATURE
                                      1        1       30000.0        1.400          20.580          545.50

                                                                       STATOR EXIT SOLUTION

STREAM    RADIAL        X=R/RM   RADIAL     BLADE     Y=VA./VAM      BLADE        LOSS          ZETA*         FLOW RATE
 LINE    POSITION                SHIFT    OPENING         .        EFFICIENCY   COEFFICIENT   CONTINUITY      FRACTION

           (IN)                   (IN)      (IN)          .
  1        2.764         .865    0.0000     .2126      1.1012        .9078         .0922        .0922         0.0000
  2        3.003         .940    0.0000     .2347      1.0468        .9055         .0945        .0945          .2601
  3        3.195        1.000     .0290     .2526      1.0000        .9036         .0964        .0964          .4815
  4        3.432        1.074    0.0000     .2745       .9403        .9019         .0981        .0981          .7628
  5        3.627        1.135    0.0000     .2926       .8907        .9006         .0994        .0994         1.0000

                         ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY        VELOCITY

  1     305.04         -12.24       673.85       739.78          305.04      -12.24       -49.77       309.32          723.62
  2     289.96           2.75       633.43       696.65          289.96        2.75      -152.78       327.76          786.21
  3     280.02           6.34       599.75       660.66          280.02        6.34      -236.83       366.80          836.58
  4     260.46          22.62       559.41       617.48          260.46       22.62      -339.00       428.11          898.41
  5     246.73          29.27       526.42       582.11          246.73       29.27      -423.13       490.68          949.55

                MACH NUMBER               FLOW ANGLE              TEMPERATURE             PRESSURE                 PRESSURE
                                            (DEG)                   (DEG. R)                (PSI)                    RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE        ABSOLUTE   RELATIVE        TOTAL     STATIC        TOTAL     STATIC         TOT/TOT     TOT/STA

  1            .67        .28           65.65      -9.27        545.50     499.96       19.921     14.683         1.0331      1.4016
  2            .63        .30           65.41     -27.79        545.50     505.12       19.985     15.268         1.0298      1.3479
  3            .60        .33           65.21     -40.23        545.50     509.18       20.037     15.743         1.0271      1.3072
  4            .56        .39           65.04     -52.47        545.50     513.77       20.100     16.298         1.0239      1.2628
  5            .52        .44           64.89     -59.76        545.50     517.30       20.150     16.734         1.0213      1.2298
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                      SET    PAGE       RPM      TOTAL/STATIC    INLET TOTAL    INLET TOTAL
                    NUMBER  NUMBER             PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                                    (PSI)        (DEG. R)

                       1       2     30000.0        1.400          20.580        545.50

                                             ROTOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS       ZETA*       FLOW RATE
 LINE   POSITION              SHIFT    OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1      2.693        .825     .0710    .1912     1.0274      .8819       .1181       .1181       0.0000
  2      3.020        .925    -.0168    .2218      .7995      .8792       .1208       .1208        .1951
  3      3.265       1.000    -.0405    .2447     1.0000      .8772       .1228       .1228        .3644
  4      3.585       1.098    -.1537    .2747     1.3181      .8871       .1130       .1130        .6688
 .5      3.837       1.175    -.2100    .2983     1.6051      .8948       .1052       .1052       1.0000

                ABSOLUTE VELOCITY (FPS)                              RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL    TANGENTIAL   OVERALL       AXIAL      RADIAL    TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT    COMPONENT   COMPONENT    VELOCITY    COMPONENT  COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1    200.40        -8.04      222.75       299.74      200.40      -8.04      -482.28      522.32       705.03
  2    155.94         1.48      432.40       459.66      155.94       1.48      -358.21      390.68       790.61
  3    195.05         4.46      421.66       464.61      195.05       4.46      -433.11      475.03       854.78
  4    257.10        22.33      401.05       476.91      257.10      22.33      -537.60      596.34       938.65
  5    313.08        37.15      379.05       493.03      313.08      37.15      -625.47      700.44      1004.53

          MACH NUMBER             FLOW ANGLE           TEMPERATURE            PRESSURE              PRESSURE
                                    (DEG)               (DEG. R)               (PSI)                  RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE     TOTAL    STATIC      TOTAL    STATIC       TOT/TOT    TOT/STA

  1        .28       .48         48.03    -67.44      490.49   483.01      13.432   12.729       1.5322     1.6168
  2        .42       .36         70.17    -66.48      519.51   501.93      16.642   14.753       1.2366     1.3950
  3        .42       .43         65.18    -65.76      521.98   504.16      16.862 - 14.931       1.2205     1.3783
  4        .43       .54         57.34    -64.45      524.51   505.58      17.868   15.008       1.2058     1.3713
  5        .45       .64         50.45    -63.41      525.68   505.45      17.120   14.923       1.2021     1.3791

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1        505.71       15.283        1.2
  2        514.63       16.299        1.1
  3        522.94       17.283        1.2
  4        535.18       18.800        1.3
  5        546.28       20.251        1.4
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                 SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
               NUMBER   NUMBER              PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                               (PSI)        (DEG. R)

                  1        3     30000.0        1.400          20.580         545.50

                             .OVERALL TURBINE CHARACTERISTICS

STREAM     PRESSURE RATIO           EFFICIENCY             HEAD       BLADE/JET     THEORETICAL
 LINE    TOT/STA    TOT/TOT     TOT/STA      TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1      1.6168     1.5322       .7863        .8787       1.6058        .7891          .2830
  2      1.3950     1.2366       .5251        .8092        .9621       1.0195          .0907
  3      1.3783     1.2205       .4922        .7790        .8205       1.1040          .1588
  4      1.3713     1.2058       .4461        .7392        .7006       1.1947          .2524
 .5      1.3791     1.2021       .4141        .7092        .6379       1.2521          .3458

                                  MASS AVERAGED QUANTITIES

                               HORSE POWER =      22.02    (HP)
                               MOMENT      =       3.86    (FT-LB)
                               FLOW RATE   =       2.53    (LB/SEC)

                      REFERRED  RPM         =  29245.32
                      REFERRED HORSE POWER =      15.33    (HP)
                      REFERRED MOMENT      =       2.75    (FT-LB)
                      REFERRED FLOW RATE   =       1.85    (LB/SEC)

                  TOTAL/STATIC EFFICIENCY =       .5159
                  TOTAL/TOTAL   EFFICIENCY=       .7803
             TOTAL/STATIC PRESSURE RATIO =      1.4106
             TOTAL/TOTAL  PRESSURE RATIO =      1.2575

            HEAD COEFFICIENT                =       .9013
            BLADE/JET SPEED RATIO           =      1.0534
            THEORETICAL DEGREE OF REACTION=         .2061
            MACH NUMBER AT STATION 0        =       .1841
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                              SET     PAGE       RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                            NUMBER   NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                               1        1      5000.0       1.600         23.520        562.23

                                                    STATOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM      BLADE        LOSS          ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                (IN)      (IN)
  1        2.764       .865   0.0000     .2126      1.1046       .9106         .0894         .0894         0.0000
  2        3.003       .940   0.0000     .2347      1.0480       .9041         .0959         .0959          .2535
  3        3.195      1.000    .0290     .2526      1.0000       .8988         .1012         .1012          .4720
  4        3.432      1.074   0.0000     .2745       .9395       .8946         .1054         .1054          .7568
  5        3.627      1.135   0.0000     .2926       .8898       .8912         .1088         .1088         1.0000

                 ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY       VELOCITY

  1      402.80      -16.16       889.81        976.87         402.80      -16.16       769.21        868.44         120.60
  2      382.17        3.63       834.86        918.19         382.17        3.63       703.83        800.90         131.03
  3      358.89        8.34       789.52        869.70         358.89        8.34       650.08        742.62         139.43
  4      342.61       29.76       735.84        812.24         342.61       29.76       586.11        679.55         149.73
  5      324.46       38.49       692.24        765.48         324.46       38.49       533.98        626.01         158.26

              MACH NUMBER              FLOW ANGLE             TEMPERATURE              PRESSURE               PRESSURE
                                         (DEG)                 (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE      TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

  1          .91        .81          65.65      62.37       562.23    482.82        22.218    13.039        1.0586      1.8038
  2          .84        .74          65.41      61.50       562.23    492.08        22.298    13.906        1.0548      1.6913
  3          .79        .68          65.21      61.10       562.23    499.29        22.372    14.765        1.0513      1.5927
  4          .74        .62          65.04      59.70       562.23    507.33        22.488    15.695        1.0459      1.4985
  5          .69        .56          64.89      58.72       562.23    513.47        22.580    16.437        1.0416      1.4309
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          SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
        NUMBER   NUMBER              PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                          (PSI)        (DEG. R)

          1        2       5000.0   .      1.600         23.520        562.23


                                                ROTOR EXIT SOLUTION


 STREAM    RADIAL       X=R/KM   RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS         ZETA*       FLOW RATE
  LINE    POSITION               SHIFT    OPENING              EFFICIENCY   COEFFICIENT   CONTINUITY   FRACTION

   1       2.693        .825     .0710     .1912       .9722       .7663        .2337        .2337        0.0000
   2       3.020        .925    -.0168     .2218      1.0017       .7647        .2353        .2353         .2414
   3       3.265       1.000    -.0405     .2447      1.0000       .7635        .2365        .2365         .4445
   4       3.585       1.098    -.1537     .2747      1.0302       .7654        .2346        .2346         .7362
   5       3.837       1.175    -.2100     .2903      1.0743       .7669        .2331        .2331        1.0000

                     ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

 STREAM    AXIAL        RADIAL      TANGENTIAL    OVERALL        AXIAL       RADIAL      TANGENTIAL    OVERALL        WHEEL
  LINE COMPONENT      COMPONENT     COMPONENT     VELOCITY     COMPONENT   COMPONENT     COMPONENT     VELOCITY       VELOCITY

   1     260.85        -10.46        -510.24       573.15        260.85      -10.46       -627.25       679.87        117.50
   2     268.75          2.55        -485.60       555.02        268.76        2.55       -617.37       673.34        131.77
   3     268.30          6.14        -453.30       526.79        268.30        6.14       -595.76       653.42        142.46
   4     276.42         24.01        -421.56       504.68        276.42       24.01       -578.00       641.15        156.44
   5     288.24         34.20        -408.42       501.06        288.24       34.20       -575.84       644.86        167.42

              MACH NUMBER              FLOW ANGLE             TEMPERATURE            PRESSURE               PRESSURE
                                         (DEG)                 (DEG. R)               (PSI)                  RATIO
 STREAM
  LINE    ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

   1         .52        .62         -62.93     -67.44       534.39    507.06       17.137    14.260       1.3725     1.6494
   2         .50        .61         -61.04     -66.48       533.37    507.74       17.101    14.393       1.3754     1.6341
   3         .48        .59         -59.38     -65.76       533.16    509.72       17.212    14.706       1.3565     1.5593
   4         .46        .58         -56.75     -64.45       532.92    511.72       17.342    15.045       1.3563     1.5633
   5         .45        .58         -54.79     -63.41       532.62    511.73       17.374    15.104       1.3537     1.5572


 STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
  LINE    TEMPERATURE    INLET        PRESSURE
                        PRESSURE        RATIO
           (DEG. R)      (PSI
   1        545.52       19.991          1.4
   2        545.47       20.057          1.4
   3        545.25       20.095          1.4
   4        545.93       20.287          1.3
   5        546.33       20.423          1.4
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                                SET     PAGE       RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                              NUMBER   NUMBER              PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                                              (PSI)         (DEG. R)

                                 1        3      5000.0   .      1.600          23.520          562.23

                                          OVERALL TURBINE CHARACTERISTICS


 STREAM        PRESSURE RATIO              EFFICIENCY               HEAD          BLADE/JET      THEORETICAL
  LINE      TOT/STA     TOT/TOT      TOT/STA         TOT/TOT     COEFFICIENT    SPEED RATIO DEGREE OF REACTION

   1        1.6494      1.3725        .3717           .5725       61.8818          .1271          -.1643
   2        1.6341      1.3754        .3921           .5897       51.5135          .1393          -.0543
   3        1.5993      1.3665        .4118           .6058       43.6353          .1514           .0079
   4        1.5633      1.3563        .4351           .6253       36.1130          .1664           .0892
   5        1.5572      1.3537        .4431           .6354       32.0649          .1766           .1813

                                          . MASS AVERAGED QUANTITIES


                                           HORSE POWER =       30.55   (HP)
                                           MOMENT      =       32.09   (FT-LB)
                                           FLOW RATE   =        3.10   (LB/SEC)

                                     REFERRED  RPM         =  4801.15
                                     REFERRED HORSE POWER  =    18.33   (HP)
                                     REFERRED MOMENT       =    20.06   (FT-LB)
                                     REFERRED FLOW RATE    =     2.02   (LB/SEC)

                                  TOTAL/STATIC EFFICIENCY  =     .4116
                                  TOTAL/TOTAL  EFFICIENCY=       .6062
                               TOTAL/STATIC PRESSURE RATIO =    1.6000
                               TOTAL/TOTAL  PRESSURE RATIO =    1.3653

                              HEAD COEFFICIENT             =   44.5588
                              BLADE/JET SPEED RATIO        =     .1498
                              THEORETICAL DEGREE OF REACTION=    .0128
                              MACH NUMBER AT STATION 0     =     .2011
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                SET      PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
              NUMBER   NUMBER              PRESSURE RATIO   PRESSURE     TEMPERATURE
                 1        1    10000.0         1.600         23.520         562.23

                                       STATOR EXIT SOLUTION

STREAM   RADIAL     X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE      LOSS        ZETA*       FLOW RATE
 LINE   POSITION             SHIFT   OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

          (IN)               (IN)     (IN)
   1     2.764      .865   0.0000    .2126     1.1044      .9084       .0916       .0916       0.0000
   2     3.003      .940   0.0000    .2347     1.0479      .9019       .0981       .0981        .2562
   3     3.195     1.000    .0290    .2526     1.0000      .8968       .1032       .1032        .4765
   4     3.432     1.074   0.0000    .2745      .9397      .8931       .1069       .1069        .7591
   5     3.627     1.135   0.0000    .2926      .8901      .8901       .1099       .1099       1.0000

                  ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT    COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

   1     371.28      -14.89       820.18       900.42        371.28      -14.89       578.97       687.95        241.21
   2     352.29        3.35       769.58       846.39        352.29        3.35       507.51       617.81        262.07
   3     320.09        7.69       727.85       801.77        320.09        7.69       448.99       551.46        278.86
   4     315.91       27.44       678.50       740.94        315.91       27.44       379.03       494.19        299.47
   5     299.23       35.50       638.43       705.97        299.23       35.50       321.91       440.94        316.52

            MACH NUMBER              FLOW ANGLE            TEMPERATURE            PRESSURE             PRESSURE
                                       (DEG)                (DEG. R)                (PSI)                RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE      ABSOLUTE  RELATIVE      TOTAL    STATIC        TOTAL    STATIC       TOT/TOT    TOT/STA

   1        .83       .63         65.65     57.33        562.23   494.77        22.407   14.325       1.0497     1.6419
   2        .77       .56         65.41     55.24        562.23   502.62        22.475   15.183       1.0465     1.5491
   3        .73       .50         65.21     54.52        562.23   508.74        22.538   15.884       1.0435     1.4807
   4        .67       .44         65.04     50.19        562.23   515.55        22.640   16.716       1.0389     1.4070
   5        .63       .39         64.89     47.09        562.23   520.76        22.720   17.376       1.0352     1.3536
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                       SET     PAGE       RPM     TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                     NUMBER   NUMBER             PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                                     (PSI)        (DEG. R)

                        1        2     10000.0       1.600          23.520        562.23

                                                 ROTOR EXIT SOLUTION

STREAM     RADIAL       X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS        ZETA*        FLOW RATE
 LINE     POSITION               SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

   1        2.693        .825    .0710     .1912      .9799       .8166       .1834       .1834        0.0000
   2        3.020        .925   -.0168     .2218      .9715       .8199       .1802       .1802         .2360
   3        3.265       1.000   -.0405     .2447     1.0000       .8223       .1777       .1777         .4344
   4        3.585       1.098   -.1537     .2747     1.0785       .8328       .1673       .1673         .7270
   5        3.837       1.175   -.2100     .2983     1.1644       .8409       .1591       .1571        1.0000

                     ABSOLUTE VELOCITY (FPS)                              RELATIVE VELOCITY (FPS)

STREAM     AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY      COMPONENT    COMPONENT    COMPONENT    VELOCITY       VELOCITY

   1     242.02        -9.71       -347.41       423.51        242.02       -9.71       -582.42       630.78        235.01
   2     239.94         2.28       -287.63       374.58        239.94        2.28       -551.17       601.14        263.54
   3     245.93         5.65       -263.49       361.19        246.98        5.65       -548.42       601.49        284.93
   4     266.38        23.14       -244.13       362.07        266.38       23.14       -557.02       617.87        312.68
   5     287.60        34.12       -239.71       375.95        287.60       34.12       -574.55       643.42        334.84

            MACH NUMBER              FLOW ANGLE              TEMPERATURE             PRESSURE              PRESSURE
                                       (DEG)                  (DEG. R)                (PSI)                 RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE       TOTAL     STATIC       TOTAL     STATIC      TOT/TOT    TOT/STA

   1        .39        .58        -55.14     -67.44        515.72    500.79      15.718    14.182       1.4964     1.6584
   2        .34        .55        -50.17     -66.48        516.05    504.37      15.899    14.675       1.4793     1.6027
   3        .33        .55        -46.86     -65.76        515.96    504.22      15.945    14.712       1.4751     1.5987
   4        .33        .56        -42.51     -64.45        515.70    504.79      16.004    14.850       1.4676     1.5838
   5        .34        .58        -39.81     -63.41        515.24    503.48      15.994    14.752       1.4706     1.5944

STREAM   EQUIVALENT    EQUIVALENT    EQUIV/STATIC
 LINE    TEMPERATURE     INLET         PRESSURE
                        PRESSURE        RATIO
           (DEG. R)      (PSI
   1        533.90       18.698          1.3
   2        534.44       18.822          1.3
   3        534.33       18.861          1.3
   4        536.56       19.224          1.3
   5        537.93       19.465          1.3
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```
   SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
 NUMBER   NUMBER              PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                 (PSI)       (DEG. R)

    1        5    10000.0         1.600         23.520        562.23

                         OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO            EFFICIENCY          HEAD       BLADE/JET      THEORETICAL
 LINE     TOT/STA    TOT/TOT      TOT/STA     TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.6584     1.4964        .6148       .7605     15.6275       .2530           .0183
  2       1.6027     1.4793        .6515       .7761     12.4023       .2840           .0675
  3       1.5987     1.4751        .6560       .7830     10.9805       .3029           .1543
  4       1.5838     1.4696        .6722       .7915      9.2752       .3284           .2450
  5       1.5944     1.4706        .6698       .8010      8.4152       .3447           .3358

                              MASS AVERAGED QUANTITIES

                                HORSE POWER =      46.17   (HP)
                                MOMENT      =      24.25   (FT-LB)
                                FLOW RATE   =       2.93   (LB/SEC)

                          REFERRED  RPM         =  9602.30
                          REFERRED HORSE POWER =     27.71   (HP)
                          REFERRED MOMENT      =     15.16   (FT-LB)
                          REFERRED FLOW RATE   =      1.91   (LB/SEC)

                       TOTAL/STATIC EFFICIENCY =      .6555
                        TOTAL/TOTAL  EFFICIENCY=      .7836
                     TOTAL/STATIC PRESSURE RATIO =   1.6029
                     TOTAL/TOTAL  PRESSURE RATIO =   1.4769

                    HEAD COEFFICIENT               =  11.1498
                    BLADE/JET SPEED RATIO          =    .2995
                    THEORETICAL DEGREE OF REACTION=     .1610
                    MACH NUMBER AT STATION 0       =    .1894
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  SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
 NUMBER  NUMBER             PRESSURE RATIO    PRESSURE     TEMPERATURE
   1       1     15000.0        1.600          23.520         562.23

                              STATOR EXIT SOLUTION

STREAM    RADIAL     X=R/RM   RADIAL     BLADE     Y=VA /VAM     BLADE        LOSS        ZETA*        FLOW RATE
 LINE    POSITION             SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY     FRACTION

           (IN)               (IN)      (IN)
   1      2.764      .865    0.0000     .2126      1.0971       .8962        .1038        .1038        0.0000
   2      3.003      .940    0.0000     .2347      1.0451       .8964        .1036        .1036         .2576
   3      3.195     1.000     .0290     .2526      1.0000       .8965        .1035        .1035         .4784
   4      3.432     1.024    0.0000     .2745       .9417       .8963        .1037        .1037         .7606
   5      3.627     1.135    0.0000     .2926       .8931       .8961        .1039        .1039        1.0000

                ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL       AXIAL      RADIAL    TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT    COMPONENT    COMPONENT     VELOCITY    COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

   1    332.10       -13.32       733.62       805.40      332.10      -13.32      371.82      498.71       361.81
   2    316.36         3.01       691.08       760.06      316.36        3.01      297.98      434.60       393.10
   3    307.42         6.93       655.37       721.93      307.42        6.93      237.00      388.28       418.29
   4    285.06        24.76       612.23       675.79      285.06       24.76      163.02      329.31       449.20
   5    270.33        32.07       576.77       637.79      270.33       32.07      102.00      299.71       474.77

          MACH NUMBER             FLOW ANGLE             TEMPERATURE            PRESSURE              PRESSURE
                                    (DEG)                 (DEG. R)               (PSI)                  RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE    ABSOLUTE  RELATIVE       TOTAL     STATIC       TOTAL    STATIC       TOT/TOT    TOT/STA

   1       .73      .45        65.65     48.23        562.23    508.25       22.523    15.820       1.0443     1.4867
   2       .68      .39        65.41     43.29        562.23    514.16       22.642    16.560       1.0388     1.4203
   3       .65      .35        65.21     37.64        562.23    518.86       22.735    17.166       1.0345     1.3701
   4       .60      .29        65.04     29.77        562.23    524.23       22.836    17.875       1.0299     1.3158
   5       .57      .26        64.89     20.67        562.23    528.38       22.914    18.438       1.0265     1.2756
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            SET      PAGE       RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
          NUMBER    NUMBER              PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                            (PSI)        (DEG. R)

             1         2      15000.0        1.600         23.520         562.23


                                                 ROTOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM    BLADE        LOSS                ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING              EFFICIENCY   COEFFICIENT    CONTINUITY    FRACTION

  1        2.693        .825     .0710     .1912       .9884      .8631         .1370          .1370        0.0000
  2        3.020        .925    -.0168     .2218       .9347      .8702         .1298          .1298         .2286
  3        3.265       1.000    -.0405     .2447      1.0000      .8756         .1245          .1245         .4226
  4        3.585       1.098    -.1537     .2747      1.1198      .8815         .1185          .1185         .7179
  5        3.837       1.175    -.2100     .2983      1.2392      .8862         .1139          .1139        1.0000


                     ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL         RADIAL     TANGENTIAL     OVERALL        AXIAL        RADIAL      TANGENTIAL     OVERALL          WHEEL
 LINE  COMPONENT      COMPONENT    COMPONENT      VELOCITY     COMPONENT     COMPONENT    COMPONENT      VELOCITY        VELOCITY

  1      238.29         -9.56       -220.95        325.11        238.29        -9.56       -573.46        621.08          352.51
  2      225.36          2.14       -122.38        256.45        225.36         2.14       -517.68        564.61          395.31
  3      241.10          5.52       -107.98        264.24        241.10         5.52       -535.37        587.18          427.39
  4      269.98         23.45        -95.22        287.24        269.98        23.45       -564.55        626.23          469.33
  5      298.76         35.45        -94.60        315.30        298.76        35.45       -596.87        668.41          502.26


               MACH NUMBER                FLOW ANGLE               TEMPERATURE                PRESSURE                    PRESSURE
                                            (DEG)                   (DEG. R)                   (PSI)                       RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE        ABSOLUTE   RELATIVE        TOTAL     STATIC           TOTAL     STATIC            TOT/TOT     TOT/STA

  1           .30        .57          -42.84     -67.44          505.09    496.30           14.930    14.039            1.5754      1.6753
  2           .23        .51          -28.50     -66.48          508.97    503.49           15.547    14.969            1.5129      1.5712
  3           .24        .53          -24.13     -65.76          508.93    503.36           15.593    15.004            1.5084      1.5676
  4           .26        .57          -19.43     -64.45          509.02    502.16           15.630    14.912            1.5041      1.5773
  5           .29        .61          -17.57     -63.41          508.75    500.47           15.616    14.745            1.5061      1.5951


STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE    INLET         PRESSURE
                         PRESSURE        RATIO
           (DEG. R)       (PSI
  1        528.40         18.126          1.3
  2        530.02         18.418          1.2
  3        532.05         18.742          1.2
  4        534.79         19.168          1.3
  5        537.65         19.595          1.3
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     SET    .PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
   NUMBER  NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                   (PSI)        (DEG. R)

      1       3    15000.0          1.600         23.520        562.23


                         OVERALL TURBINE CHARACTERISTICS


STREAM     PRESSURE RATIO          EFFICIENCY           HEAD       BLADE/JET     THEORETICAL
 LINE    TOT/STA    TOT/TOT    TOT/STA     TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.6753     1.5754     .7414       .8345      7.0747        .3760           .2185
  2       1.5712     1.5129     .7822       .8492      5.2951        .4346           .2124
  3       1.5676     1.5084     .7866       .8556      4.6545        .4635           .2861
  4       1.5773     1.5041     .7752       .8598      4.0076        .4946           .3822
  5       1.5951     1.5061     .7617       .8615      3.7435        .5168           .4620


                               MASS AVERAGED QUANTITIES


                             HORSE POWER =      54.17   (HP)
                             MOMENT      =      18.97   (FT-LB)
                             FLOW RATE   =       2.97   (LB/SEC)

                   REFERRED  RPM         =   14403.46
                   REFERRED HORSE POWER =      32.51   (HP)
                   REFERRED MOMENT       =      11.86   (FT-LB)
                   REFERRED FLOW RATE    =       1.93   (LB/SEC)

              TOTAL/STATIC EFFICIENCY =         .7739
              TOTAL/TOTAL  EFFICIENCY=          .8532
           TOTAL/STATIC PRESSURE RATIO =       1.5878
           TOTAL/TOTAL  PRESSURE RATIO =       1.5165

         HEAD COEFFICIENT                 =    4.8616
         BLADE/JET SPEED RATIO            =     .4535
         THEORETICAL DEGREE OF REACTION=        .3052
         MACH NUMBER AT STATION 0         =     .1[illegible]
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      SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
    NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
      1        1      20000.0        1.600         23.520          562.23

                                         STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM    BLADE       LOSS         ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING                 EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

           (IN)                 (IN)      (IN)
  1        2.764        .865   0.0000     .2126      1.0995      .9033        .0967        .0967        0.0000
  2        3.003        .940   0.0000     .2347      1.0461      .9019        .0981        .0981         .2585
  3        3.195       1.000    .0290     .2526      1.0000      .9009        .0991        .0991         .4795
  4        3.432       1.074   0.0000     .2745       .9409      .8998        .1002        .1002         .7614
  5        3.627       1.135   0.0000     .2926       .8917      .8989        .1011        .1011        1.0000

                    ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL     TANGENTIAL    OVERALL          AXIAL      RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT    COMPONENT    COMPONENT     VELOCITY       COMPONENT  COMPONENT    COMPONENT     VELOCITY        VELOCITY

  1     326.89      -13.11       722.13       792.78         326.89     -13.11       239.72        405.58          482.41
  2     311.01        2.95       679.40       747.21         311.01       2.95       155.26        347.62          524.14
  3     302.56        6.80       643.70       709.08         302.56       6.80        85.98        314.61          557.72
  4     279.73       24.29       600.78       663.15         279.73      24.29         1.84        280.79          598.94
  5     265.11       31.45       565.62       625.46         265.11      31.45       -67.41        275.35          633.03

              MACH NUMBER              FLOW ANGLE              TEMPERATURE            PRESSURE               PRESSURE
                                         (DEG)                  (DEG. R)               (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE       TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1          .72        .37          65.65      36.26        562.23    509.93       22.628    16.078       1.0394     1.4628
  2          .67        .31          65.41      26.53        562.23    515.77       22.724    16.803       1.0350     1.3798
  3          .63        .28          65.21      15.86        562.23    520.39       22.800    17.394       1.0316     1.3522
  4          .59        .25          65.04        .38        562.23    525.64       22.888    18.084       1.0276     1.3006
  5          .55        .24          64.89     -14.27        562.23    529.68       22.956    18.631       1.0246     1.2624
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                    SET     PAGE        RPM       TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                  NUMBER   NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                                   (PSI)        (DEG. R)

                     1        2      20000.0        1.600          23.520        562.23

                                                   ROTOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM     BLADE       LOSS         ZETA*       FLOW RATE
 LINE   POSITION              SHIFT    OPENING        .       EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1      2.693        .825    .0710     .1912      .9981       .8889       .1111        .1111       0.0000
  2      3.020        .925   -.0168     .2218      .8994       .8926       .1074        .1074        .2215
  3      3.265       1.000   -.0405     .2447     1.0000       .8954       .1046        .1046        .4105
  4      3.585       1.098   -.1537     .2747     1.1697       .8043       .1157        .1157        .7083
  5      3.837       1.175   -.2100     .2983     1.3310       .8756       .1245        .1245       1.0000

                    ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL   OVERALL        AXIAL      RADIAL    TANGENTIAL   OVERALL       WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT    VELOCITY     COMPONENT  COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1     234.59        -9.41       -94.53      253.10       234.59      -9.41      -564.55      611.42       470.02
  2     211.40         2.01        41.47      215.44       211.40       2.01      -485.61      529.63       527.07
  3     235.03         5.38        47.96      239.94       235.03       5.38      -521.89      572.40       569.85
  4     274.92        23.88        50.90      280.61       274.92      23.88      -574.87      637.68       625.77
  5     312.84        37.12        44.70      318.19       312.84      37.12      -624.98      699.89       669.68

           MACH NUMBER              FLOW ANGLE              TEMPERATURE            PRESSURE              PRESSURE
                                      (DEG)                  (DEG. R)               (PSI)                 RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE       TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1         .23       .56        -21.95    -67.44       496.86    491.53       14.279    13.750       1.6472     1.7106
  2         .20       .48         11.10    -66.48       506.60    502.74       15.474    15.065       1.5200     1.5612
  3         .22       .52         11.53    -65.76       507.03    502.50       15.531    15.051       1.5144     1.5627
  4         .26       .58         10.49    -64.45       507.65    501.09       15.519    14.830       1.5155     1.5860
  5         .29       .64          8.13    -63.41       507.62    499.20       15.411    14.535       1.5262     1.6182

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE    TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1        522.64       17.525        1.3
  2        526.08       18.008        1.2
  3        529.77       18.515        1.2
  4        534.93       19.229        1.3
  5        539.96       19.928        1.4
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                 SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                NUMBER  NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                             (PSI)        (DEG. R)

                  1        3     20000.0        1.600        23.520        562.23


                          .OVERALL TURBINE CHARACTERISTICS


 STREAM      PRESSURE RATIO          EFFICIENCY           HEAD        BLADE/JET     THEORETICAL
  LINE     TOT/STA   TOT/TOT     TOT/STA      TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

   1       1.7106    1.6472       .8177        .8750      4.1282        .4922          .2757
   2       1.5612    1.5200       .8279        .8776      2.9392        .5833          .2334
   3       1.5627    1.5144       .8199        .8780      2.6011        .6200          .3102
   4       1.5860    1.5155       .7864        .8668      2.3254        .6558          .4141
   5       1.6182    1.5262       .7560        .8537      2.1662        .6794          .4987


                               MASS AVERAGED QUANTITIES


                            HORSE POWER =      56.33   (HP)
                            MOMENT      =      14.79   (FT-LB)
                            FLOW RATE   =       2.95   (LB/SEC)


                 REFERRED  RPM          =  19204.61
                 REFERRED HORSE POWER   =      33.81   (HP)
                 REFERRED MOMENT        =       9.25   (FT-LB)
                 REFERRED FLOW RATE     =       1.92   (LB/SEC)

              TOTAL/STATIC EFFICIENCY =        .8052
              TOTAL/TOTAL  EFFICIENCY=         .8717
           TOTAL/STATIC PRESSURE RATIO =      1.5936
           TOTAL/TOTAL  PRESSURE RATIO =      1.5342

           HEAD COEFFICIENT               =   2.7532
           BLADE/JET SPEED RATIO          =    .6027
           THEORETICAL DEGREE OF REACTION=     .3362
           MACH NUMBER AT STATION 0       =    .1912
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                               SET     PAGE      RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                              NUMBER  NUMBER            PRESSURE RATIO    PRESSURE      TEMPERATURE
                                 1       1    25000.0        1.600          23.520         562.23

                                                        STATOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM     BLADE       LOSS        /ETA*       FLOW RATE
 LINE    POSITION               SHIFT   OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

           (IN)                 (IN)     (IN)
  1       2.764       .865     0.0000    .2126      1.1009      .9084        .0916       .0916        0.0000
  2       3.003       .940     0.0000    .2347      1.0467      .9063        .0937       .0937         .2584
  3       3.195      1.000      .0290    .2526      1.0000      .9047        .0953       .0953         .4794
  4       3.432      1.074     0.0000    .2745       .9403      .9031        .0969       .0969         .7613
  5       3.627      1.135     0.0000    .2926       .8908      .9018        .0982       .0982        1.0000

                    ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY      COMPONENT    COMPONENT   COMPONENT     VELOCITY      VELOCITY

  1     332.96        -13.36        735.53       807.49        332.96       -13.36       132.52       358.61       603.01
  2     316.55          3.01        691.51       760.53        316.55         3.01        36.34       318.65       655.17
  3     302.44          6.92        654.81       721.32        302.44         6.92       -42.34       305.47       697.15
  4     284.39         24.70        610.80       674.22        284.39        24.70      -137.87       317.01       746.67
  5     269.41         31.96        574.81       635.61        269.41        31.96      -216.49       347.09       791.29

               MACH NUMBER              FLOW ANGLE              TEMPERATURE             PRESSURE                PRESSURE
                                          (DEG)                  (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE       TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

  1          .73        .32           65.65      21.70        562.23    507.97        22.646    15.875        1.0386      1.4815
  2          .68        .29           65.41       6.55        562.23    514.10        22.733    16.620        1.0346      1.4152
  3          .65        .27           65.21      -7.97        562.23    518.93        22.804    17.227        1.0314      1.3653
  4          .60        .28           65.04     -25.87        562.23    524.40        22.889    17.937        1.0276      1.3112
  5          .56        .31           64.89     -38.79        562.23    528.61        22.955    18.499        1.0246      1.2714
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                                SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                              NUMBER   NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                                                (PSI)        (DEG. R)

                                  1        2    25000.0          1.600          23.520         562.23


                                                           ROTOR EXIT SOLUTION


STREAM     RADIAL        X=R/RM    RADIAL     BLADE       Y=VA /VAM      BLADE         LOSS           ZETA*          FLOW RATE
 LINE     POSITION                 SHIFT    OPENING                   EFFICIENCY    COEFFICIENT    CONTINUITY      FRACTION

  1         2.693          .825     .0710     .1912       1.0078         .9033         .0960          .0960          0.0000
  2         3.020          .925    -.0168     .2218        .8666         .8845         .1156          .1156           .2132
  3         3.275         1.000    -.0405     .2447       1.0000         .8704         .1297          .1297           .3955
  4         3.585         1.098    -.1537     .2747       1.2198         .8796         .1204          .1204           .6949
  5         3.837         1.175    -.2100     .2983       1.4240         .8069         .1132          .1132          1.0000


                  ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL      TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT       COMPONENT     COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY       VELOCITY

  1      233.41         -9.36         25.81        235.02          233.41      -9.36      -561.71       608.35         587.52
  2      200.70          1.91        197.80        281.80          200.70       1.91      -461.04       502.83         658.84
  3      231.59          5.30        198.07        304.78          231.59       5.30      -514.25       564.02         713.31
  4      282.50         24.54        191.49        342.17          282.50      24.54      -590.72       655.25         782.21
  5      329.78         39.13        178.27        376.92          329.78      39.13      -656.83       737.80         837.11


           MACH NUMBER                  FLOW ANGLE               TEMPERATURE              PRESSURE                  PRESSURE
                                          (DEG)                   (DEG. R)                 (PSI)                     RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE        TOTAL      STATIC       TOTAL      STATIC        TOT/TOT     TOT/STA

  1          .22        .56            6.31     -67.44        490.94     486.34       13.757     13.312        1.7096      1.7669
  2          .26        .46           44.59     -66.48        508.52     501.91       15.692     14.990        1.4988      1.5690
  3          .28        .51           40.54     -65.76        509.74     502.01       15.741     14.921        1.4942      1.5763
  4          .31        .60           34.13     -64.45        511.05     501.31       15.836     14.805        1.4852      1.5887
  5          .34        .67           28.40     -63.41        511.37     499.55       15.815     14.572        1.4872      1.6141


STREAM    EQUIVALENT     EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE     INLET          PRESSURE
                          PRESSURE        RATIO
           (DEG. R)        (PSI
  1         517.14         16.901          1.3
  2         522.95         17.643          1.2
  3         528.48         18.361          1.2
  4         537.04         19.496          1.3
  5         544.64         20.565          1.4
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         SET    PAGE      RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
        NUMBER  NUMBER            PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                    (PSI)         (DEG. R)

           1      3     25000.0       1.600         23.520        562.23


                               OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO           EFFICIENCY           HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.7669     1.7896      .8448        .8926      2.7088        .5988           .2922
  2       1.5690     1.4988      .7911        .8750      1.9008        .7253           .2179
  3       1.5763     1.4942      .7658        .8614      1.6948        .7681           .3018
  4       1.5887     1.4852      .7348        .8518      1.4933        .8183           .3986
  5       1.6141     1.4872      .7076        .8438      1.3796        .8514           .4814


                                    MASS AVERAGED QUANTITIES


                                  HORSE POWER =       53.63   (HP)
                                  MOMENT      =       11.27   (FT-LB)
                                  FLOW RATE   =        2.92   (LB/SEC)


                         REFERRED  RPM         =  24005.76
                         REFFRRED HORSE POWER =       32.19   (HP)
                         REFFRRED MOMENT      =        7.04   (FT-LB)
                         REFFRRED FLOW RATE   =        1.90   (LB/SEC)


                     TOTAL/STATIC EFFICIENCY =        .7670
                     TOTAL/TOTAL  EFFICIENCY=         .8641
                  TOTAL/STATIC PRESSURE RATIO =      1.6061
                  TOTAL/TOTAL  PRESSURE RATIO =      1.5192


                HEAD COEFFICIENT                =    1.7933
                BLADE/JET SPEED RATIO           =     .7468
                THEORETICAL DEGREE OF REACTION=       .3263
                MACH NUMBER AT STATION 0        =     .1889
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                    SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                  NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                    1        1      30000.0        1.600         23.520          562.23


                                                   STATOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL     BLADE     Y=VA /VAM      BLADE         LOSS          ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                 (IN)      (IN)
  1        2.764       .865    0.0000     .2126      1.1019        .9121        .0879         .0879         0.0000
  2        3.003       .940    0.0000     .2347      1.0471        .9094        .0906         .0906          .2580
  3        3.195      1.000     .0290     .2526      1.0000        .9072        .0928         .0928          .4789
  4        3.432      1.074    0.0000     .2745       .9400        .9053        .0947         .0947          .7609
  5        3.627      1.135    0.0000     .2926       .8902        .9038        .0962         .0962         1.0000


                 ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL   OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT    VELOCITY     COMPONENT   COMPONENT   COMPONENT     VELOCITY        VELOCITY

  1     341.40       -13.69       754.17       827.96       341.40      -13.69       30.56       343.04          723.62
  2     324.41         3.08       708.67       779.40       324.41        3.08      -77.53       333.56          786.21
  3     305.59         7.09       670.80       738.93       305.59        7.09     -165.70       347.73          836.58
  4     291.23        25.29       625.48       690.42       291.23       25.29     -272.93       399.93          898.41
  5     275.81        32.72       588.46       650.71       275.81       32.72     -361.09       455.55          949.55


            MACH NUMBER               FLOW ANGLE             TEMPERATURE             PRESSURE               PRESSURE
                                        (DEG)                 (DEG. R)                (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT     TOT/STA

  1          .75        .31         65.65       5.12       562.23    505.19       22.636    15.566       1.0391      1.5110
  2          .70        .30         65.41     -13.44       562.23    511.68       22.719    16.338       1.0352      1.4395
  3          .66        .31         65.21     -28.48       562.23    516.80       22.788    16.968       1.0321      1.3862
  4          .62        .36         65.04     -43.15       562.23    522.56       22.873    17.706       1.0283      1.3284
  5          .58        .40         64.89     -52.63       562.23    527.00       22.939    18.290       1.0253      1.2860
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  SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
 NUMBER  NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                 (PSI)       (DEG. R)

   1       2      30000.0       1.600           23.520        562.23

                                     ROTOR EXIT SOLUTION

STREAM  RADIAL     X=R/RM   RADIAL   BLADE    Y=VA /VAM   BLADE      LOSS         ZETA*       FLOW RATE
 LINE   POSITION            SHIFT   OPENING             EFFICIENCY COEFFICIENT  CONTINUITY   FRACTION

  1      2.693       .825   .0710    .1912    1.0177      .8859      .1142        .1142       0.0000
  2      3.020       .925  -.0168    .2218     .8324      .8803      .1197        .1197        .2019
  3      3.265      1.000  -.0405    .2447    1.0000      .8761      .1239        .1239        .3775
  4      3.585      1.098  -.1537    .2747    1.2735      .8864      .1136        .1136        .6802
  5      3.837      1.175  -.2100    .2983    1.5233      .8946      .1055        .1055       1.0000

               ABSOLUTE VELOCITY (FPS)                             RELATIVE VELOCITY (FPS)

STREAM   AXIAL      RADIAL    TANGENTIAL   OVERALL      AXIAL      RADIAL    TANGENTIAL   OVERALL      WHEEL
 LINE  COMPONENT  COMPONENT   COMPONENT    VELOCITY   COMPONENT  COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1     230.49      -9.25      150.36      275.35      230.49      -9.25      -554.67      600.72       705.03
  2     188.52       1.79      357.56      404.22      188.52       1.79      -433.05      472.31       790.61
  3     226.47       5.18      351.91      418.51      226.47       5.18      -502.87      551.54       854.78
  4     288.41      25.05      335.58      443.19      288.41      25.05      -603.08      668.96       938.65
  5     344.98      40.93      315.33      469.17      344.98      40.93      -689.19      771.80      1004.53

            MACH NUMBER             FLOW ANGLE            TEMPERATURE            PRESSURE              PRESSURE
                                      (DEG)                (DEG. R)               (PSI)                 RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE     TOTAL    STATIC       TOTAL    STATIC       TOT/TOT    TOT/STA

  1         .26        .56        33.12     -67.44      489.05    482.74      13.508    12.908       1.7411     1.8221
  2         .37        .43        62.20     -66.48      516.55    502.95      16.594    15.115       1.4174     1.5561
  3         .38        .50        57.24     -65.76      518.90    504.11      16.786    15.170       1.4011     1.5504
  4         .40        .61        49.33     -64.45      521.13    504.79      16.963    15.173       1.3865     1.5501
  5         .43        .70        42.43     -63.41      521.95    503.64      16.976    14.981       1.3854     1.5700

STREAM  EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE   TEMPERATURE  INLET         PRESSURE
                     PRESSURE        RATIO
         (DEG. R)    (PSI
  1      512.77       16.399         1.3
  2      521.52       17.464         1.2
  3      529.42       18.463         1.2
  4      542.03       20.123         1.3
  5      553.20       21.676         1.4
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                        SET    PAGE      RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                       NUMBER  NUMBER             PRESSURE RATIO   PRESSURE       TEMPERATURE
                                                                     (PSI)         (DEG. R)

                         1       3     30000.0        1.600         23.520          562.23

                                       OVERALL TURBINE CHARACTERISTICS

STREAM       PRESSURE RATIO              EFFICIENCY              HEAD        BLADE/JET      THEORETICAL
 LINE     TOT/STA     TOT/TOT      TOT/STA        TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1      1.8221      1.7411        .8263          .8884        2.0327          .7014            .2938
   2      1.5561      1.4174        .6846          .8565        1.2972          .8780            .1669
   3      1.5504      1.4011        .6545          .8390        1.1368          .9379            .2435
   4      1.5501      1.3865        .6210          .8200         .9854         1.0074            .3380
   5      1.5700      1.3854        .5925          .8055         .9060         1.0506            .4265

                                           MASS AVERAGED QUANTITIES

                                      HORSE POWER =       45.44    (HP)
                                      MOMENT      =        7.96    (FT-LB)
                                      FLOW RATE   =        2.93    (LB/SEC)

                                 REFERRED  RPM         =  28806.91
                                 REFERRED HORSE POWFR  =     27.27    (HP)
                                 REFERRED MOMFNT       =      4.97    (FT-LB)
                                 REFERRED FLOW RATE    =      1.91    (LB/SEC)

                              TOTAL/STATIC EFFICIENCY =      .6674
                              TOTAL/TOTAL  EFFICIENCY=       .8406
                           TOTAL/STATIC PRESSURE RATIO =    1.5882
                           TOTAL/TOTAL  PRESSURE RATIO =    1.4421

                        HEAD COEFFICIENT               =    1.2222
                        BLADE/JET SPEED RATIO          =     .9045
                        THEORETICAL DEGREE OF REACTION=      .2771
                        MACH NUMBER AT STATION 0       =     .1898
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                                SET     PAGE        RPM       TOTAL/STATIC      INLET TOTAL   INLET TOTAL
                              NUMBER   NUMBER               PRESSURE RATIO     PRESSURE      TEMPERATURE
                                 1        1       5000.0         1.800          26.460          557.30


                                                          STATOR EXIT SOLUTION


  STREAM    RADIAL          X=R/RM    RADIAL     BLADE        Y=VA /VAM      BLADE         LOSS           ZETA*          FLOW RATE
   LINE    POSITION                   SHIFT     OPENING           .       EFFICIENCY    COEFFICIENT     CONTINUITY      FRACTION

             (IN)                     (IN)       (IN)
    1        2.764           .865     0.0000     .2126         1.1053        .9157          .0843          .0843          0.0000
    2        3.003           .940     0.0000     .2347         1.0484        .9088          .0912          .0912           .2504
    3        3.195          1.000      .0290     .2526         1.0000        .9033          .0967          .0967           .4689
    4        3.432          1.074     0.0000     .2745          .9390        .8983          .1017          .1017           .7530
    5        3.627          1.135     0.0000     .2926          .8888        .8941          .1059          .1059          1.0000


                          ABSOLUTE VELOCITY (FPS)                                        RELATIVE VELOCITY (FPS)

  STREAM     AXIAL        RADIAL      TANGENTIAL     OVERALL             AXIAL        RADIAL      TANGENTIAL     OVERALL            WHEEL
   LINE  COMPONENT      COMPONENT     COMPONENT      VELOCITY          COMPONENT    COMPONENT     COMPONENT      VELOCITY          VELOCITY

    1      439.17        -17.62         970.14        1065.06            439.17       -17.62        849.54        956.50            120.60
    2      416.55          3.96         909.97        1000.79            416.55         3.96        778.93        883.33            131.03
    3      402.67          9.09         860.27         947.64            402.67         9.09        720.84        825.73            139.43
    4      373.11         32.41         801.34         884.53            373.11        32.41        651.60        751.56            149.73
    5      353.15         41.90         753.46         833.17            353.15        41.90        595.20        693.35            158.26


                  MACH NUMBER                FLOW ANGLE               TEMPERATURE              PRESSURE                 PRESSURE
                                               (DEG)                   (DEG. R)                 (PSI)                    RATIO
  STREAM
   LINE     ABSOLUTE   RELATIVE         ABSOLUTE   RELATIVE          TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

    1          1.01       .91             65.65      62.67           557.30    462.91        24.762    12.933        1.0686      2.0459
    2           .94       .83             65.41      61.87           557.30    473.96        24.862    14.103        1.0643      1.8762
    3           .88       .77             65.21      60.82           557.30    482.57        24.957    15.078        1.0602      1.7548
    4           .81       .69             65.04      60.21           557.30    492.20        25.098    16.249        1.0543      1.6285
    5           .76       .63             64.89      59.32           557.30    499.54        25.213    17.191        1.0495      1.5392
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                        SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                      NUMBER   NUMBER            PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                   (PSI)         (DEG. R)

                         1        2     5000.0       1.800         26.460         557.30


                                              ROTOR EXIT SOLUTION

STREAM   RADIAL     X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS        ZETA*       FLOW RATE
 LINE    POSITION            SHIFT    OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1       2.693      .825    .0710    .1912      .9717      .7723       .2278       .2278       0.0000
  2       3.020      .925   -.0168    .2218     1.0028      .7702       .2298       .2298        .2402
  3       3.265     1.000   -.0405    .2447     1.0000      .7687       .2313       .2313        .4435
  4       3.585     1.098   -.1537    .2747     1.0235      .7666       .2335       .2335        .7363
  5       3.837     1.175   -.2100    .2983     1.0613      .7649       .2352       .2352       1.0000

              ABSOLUTE VELOCITY (FPS)                             RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL    TANGENTIAL   OVERALL      WHEEL
 LINE   COMPONENT   COMPONENT   COMPONENT    VELOCITY    COMPONENT   COMPONENT  COMPONENT    VELOCITY    VELOCITY

  1      298.76      -11.98     -601.46      671.68      298.76     -11.98     -718.97      778.66      117.50
  2      308.34        2.93     -576.53      653.81      308.34       2.93     -708.29      772.50      131.77
  3      307.47        7.04     -540.27      621.68      307.47       7.04     -682.74      748.81      142.46
  4      314.69       27.33     -501.59      592.77      314.69      27.33     -658.03      729.92      156.44
  5      326.33       38.72     -484.51      585.44      326.33      38.72     -651.94      730.08      167.42

             MACH NUMBER              FLOW ANGLE            TEMPERATURE           PRESSURE              PRESSURE
                                         (DEG)                (DEG. R)              (PSI)                 RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE       ABSOLUTE  RELATIVE       TOTAL    STATIC       TOTAL    STATIC       TOT/TOT   TOT/STA

  1         .62       .72          -63.59    -67.44       526.07    488.52       18.159   14.014       1.4571    1.8882
  2         .60       .71          -61.87    -66.48       524.81    489.24       18.093   14.152       1.4625    1.8697
  3         .57       .69          -60.36    -65.76       524.53    492.72       18.244   14.657       1.4503    1.8053
  4         .54       .67          -57.90    -64.45       524.27    495.03       18.397   15.049       1.4383    1.7582
  5         .54       .67          -56.04    -63.41       523.96    495.44       18.425   15.147       1.4361    1.7468


STREAM   EQUIVALENT    EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE    INLET        PRESSURE
                        PRESSURE      RATIO
          (DEG. R)      (PSI
  1       538.98         22.027        1.6
  2       538.90         22.106        1.6
  3       539.38         22.259        1.5
  4       539.37         22.384        1.5
  5       539.79         22.547        1.5
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                         SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER              PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                                       (PSI)       (DEG. R)

                          1       3      5000.0         1.800         26.460        557.30

                                        OVERALL TURBINE CHARACTERISTICS

STREAM     PRESSURE RATIO             EFFICIENCY            HEAD        BLADE/JET     THEORETICAL
 LINE    TOT/STA    TOT/TOT     TOT/STA       TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1      1.6882     1.4571       .3375         .5496       76.4640        .1144          -.1139
  2      1.9697     1.4625       .3561         .5664       63.8575        .1251          -.0051
  3      1.8053     1.4563       .3787         .5835       53.4993        .1367           .0442
  4      1.7582     1.4383       .3980         .6009       44.4777        .1499           .1266
  5      1.7460     1.4361       .4062         .6091       39.3928        .1593           .2131

                                             MASS AVERAGED QUANTITIES

                                          HORSE POWER =      40.80    (HP)
                                          MOMENT      =      42.85    (FT-LB)
                                          FLOW RATE   =       3.68    (LB/SEC)

                                  REFERRED  RPM          =  4022.34
                                  REFERRED HORSE POWER =     21.96    (HP)
                                  REFERRED MOMENT      =     23.81    (FT-LB)
                                  REFERRED FLOW RATE   =      2.12    (LB/SEC)

                               TOTAL/STATIC EFFICIENCY =      .3761
                               TOTAL/TOTAL  EFFICIENCY=       .5825
                           TOTAL/STATIC PRESSURE RATIO =     1.8127
                           TOTAL/TOTAL  PRESSURE RATIO =     1.4494

                         HEAD COEFFICIENT              =    54.9407
                         BLADE/JET SPEED RATIO         =      .1349
                         THEORETICAL DEGREE OF REACTION=      .0538
                         MACH NUMBER AT STATION 0      =      .2117
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          SET      PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
        NUMBER   NUMBER              PRESSURE RATIO    PRESSURE      TEMPERATURE
           1        1     10000.0        1.800          26.460         557.30

                                          STATOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM     BLADE        LOSS          ZETA*        FLOW RATE
 LINE    POSITION             SHIFT   OPENING                EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

           (IN)               (IN)     (IN)
   1      2.764       .865   0.0000    .2126     1.1035        .9052        .0940         .0940         0.0000
   2      3.003       .940   0.0000    .2347     1.0475        .8991        .1009         .1009          .2544
   3      3.195      1.000    .0290    .2526     1.0000        .8942        .1058         .1058          .4742
   4      3.432      1.074   0.0000    .2745      .9402        .8911        .1089         .1089          .7575
   5      3.627      1.135   0.0000    .2926      .8910        .8885        .1115         .1115         1.0000

                      ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL        AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

   1    387.07        -15.53       855.05        938.71        387.07      -15.53       613.85        725.86        241.21
   2    367.44          3.49       802.69        882.80        367.44        3.49       540.62        653.68        262.07
   3    350.78          8.03       759.46        836.60        350.78        8.03       480.60        595.05        278.86
   4    329.81         28.64       708.35        781.89        329.81       28.64       408.88        526.10        299.47
   5    312.54         37.08       666.82        737.36        312.54       37.08       350.30        470.92        316.52

              MACH NUMBER                FLOW ANGLE              TEMPERATURE              PRESSURE                  PRESSURE
                                           (DEG)                   (DEG. R)                (PSI)                      RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE        TOTAL     STATIC        TOTAL     STATIC          TOT/TOT    TOT/STA

   1         .87        .67          65.65      57.77          557.30    493.98        25.020    15.270          1.0576     1.7328
   2         .81        .60          65.41      55.80          557.30    492.45        25.117    16.290          1.0535     1.6243
   3         .76        .54          65.21      53.88          557.30    499.06        25.204    17.127          1.0499     1.5419
   4         .71        .48          65.04      51.11          557.30    506.43        25.340    18.126          1.0442     1.4598
   5         .66        .42          64.89      48.26          557.30    512.06        25.447    18.921          1.0398     1.3985
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                            SET     PAGE       RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                           NUMBER  NUMBER             PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                                         (PSI)        (DEG. R)

                             1       2     10000.0        1.800         26.460        557.30

                                                        ROTOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL     BLADE     Y=VA /VAM    BLADE      LOSS         ZETA*       FLOW RATE
 LINE   POSITION              SHIFT     OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

  1      2.693        .825   -.0710     .1912      .9784       .8232       .1768        .1768        0.0000
  2      3.020        .925   -.0168     .2218      .9764       .8245       .1755        .1755         .2363
  3      3.265       1.000   -.0405     .2447     1.0000       .8255       .1745        .1745         .4364
  4      3.585       1.098   -.1537     .2747     1.0638       .8335       .1666        .1666         .7296
  5      3.837       1.175   -.2100     .2983     1.1358       .8397       .1603        .1603        1.0000

                  ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL    TANGENTIAL   OVERALL       AXIAL       RADIAL     TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT     COMPONENT   COMPONENT    VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1     279.90       -11.23      -438.57      520.40       279.90      -11.23      -673.58      729.51       235.01
  2     279.04         2.65      -377.45      469.40       279.04        2.65      -640.98      699.09       263.54
  3     286.08         6.55      -350.30      452.32       286.08        6.55      -635.23      696.71       284.93
  4     304.34        26.43      -323.50      444.94       304.34       26.43      -636.39      705.91       312.08
  5     324.93        38.55      -314.30      453.71       324.93       38.55      -649.14      726.95       334.84

          MACH NUMBER            FLOW ANGLE           TEMPERATURE           PRESSURE             PRESSURE
                                   (DEG)               (DEG. R)              (PSI)                RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE    ABSOLUTE  RELATIVE     TOTAL    STATIC      TOTAL    STATIC      TOT/TOT   TOT/STA

  1        .48       .68       -57.46    -67.44      505.82   483.29      16.625   14.174      1.5916    1.8668
  2        .43       .65       -53.53    -66.48      505.74   487.40      16.794   14.758      1.5756    1.7929
  3        .42       .64       -50.77    -65.76      505.44   488.42      16.834   14.932      1.5718    1.7721
  4        .41       .65       -46.75    -64.45      505.15   488.68      16.923   15.069      1.5636    1.7559
  5        .42       .67       -44.05    -63.41      504.66   487.53      16.921   14.994      1.5638    1.7647

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE    INLET        PRESSURE
                       PRESSURE        RATIO
          (DEG. R)      (PSI
  1       527.57        20.652          1.5
  2       528.07        20.801          1.4
  3       528.81        20.975          1.4
  4       530.14        21.275          1.4
  5       531.50        21.558          1.4
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     SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
   NUMBER   NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                 (PSI)        (DEG. R)

      1        3     10000.0        1.800        26.460         557.30

                       .OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO          EFFICIENCY           HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT   COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       1.8668     1.5916      .5655        .7429     10.8039        .2306          .1102
  2       1.7929     1.5756      .6022        .7596     14.9821        .2584          .1576
  3       1.7721     1.5718      .6170        .7677     12.9877        .2775          .2250
  4       1.7559     1.5636      .6298        .7806     11.0959        .3002          .3105
  5       1.7647     1.5638      .6306        .7877     10.0133        .3160          .3900

                               MASS AVERAGED QUANTITIES

                               HORSE POWER =       62.51   (HP)
                               MOMENT      =       32.83   (FT-LB)
                               FLOW RATE   =        3.54   (LB/SEC)

                        REFERRED  RPM          =  9644.68
                        REFERRED HORSE POWER =      33.50   (HP)
                        REFERRED MOMENT      =      18.24   (FT-LB)
                        REFERRED FLOW RATE   =       2.04   (LB/SEC)

                    TOTAL/STATIC EFFICIENCY =        .6118
                    TOTAL/TOTAL  EFFICIENCY=         .7683
                  TOTAL/STATIC PRESSURE RATIO =     1.7842
                  TOTAL/TOTAL  PRESSURE RATIO =     1.5722

                HEAD COEFFICIENT               =   13.3684
                BLADE/JET SPEED RATIO          =     .2735
                THEORETICAL DEGREE OF REACTION=      .2358
                MACH NUMBER AT STATION 0       =     .2036
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                          SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                        NUMBER   NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
                           1        1     15000.0         1.800          26.460         557.30


                                                           STATOR EXIT SOLUTION


 STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE        LOSS          ZETA*        FLOW RATE
  LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

            (IN)                 (IN)      (IN)
   1        2.764        .865   0.0000     .2126       1.0986         .9007         .0993         .0993       0.0000
   2        3.003        .940   0.0000     .2347       1.0456         .8995         .1005         .1005        .2550
   3        3.195       1.000    .0290     .2526       1.0000         .8986         .1014         .1014        .4750
   4        3.432       1.074   0.0000     .2745        .9415         .8984         .1016         .1016        .7582
   5        3.627       1.135   0.0000     .2926        .8929         .8982         .1018         .1018       1.0000

                     ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

 STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL   OVERALL         WHEEL
  LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY     COMPONENT  COMPONENT    COMPONENT    VELOCITY       VELOCITY

   1     367.32        -14.73       811.42        890.81       367.32     -14.73        449.61      580.76         361.81
   2     349.62          3.32       763.74        839.96       349.62       3.32        370.64      509.52         393.10
   3     338.52          7.65       723.92        797.44       338.52       7.65        305.62      456.13         418.29
   4     314.81         27.34       676.12        746.32       314.81      27.34        226.92      389.03         449.20
   5     298.55         35.42       636.97        704.35       298.55      35.42        162.19      341.60         474.77

              MACH NUMBER               FLOW ANGLE             TEMPERATURE              PRESSURE                PRESSURE
                                          (DEG)                 (DEG. R)                 (PSI)                    RATIO
 STREAM
  LINE    ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE       TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

   1         .82        .53          65.65      50.76        557.30     491.27       25.113    16.151        1.0536      1.6383
   2         .77        .47          65.41      46.68        557.30     498.59       25.262    17.111        1.0474      1.5464
   3         .72        .41          65.21      42.08        557.30     504.39       25.380    17.900        1.0426      1.4782
   4         .67        .35          65.04      35.79        557.30     510.95       25.522    18.834        1.0367      1.4049
   5         .63        .31          64.89      28.52        557.30     516.02       25.630    19.578        1.0324      1.3515
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      SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
    NUMBER   NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                   (PSI)        (DEG. R)

       1        2     15000.0        1.800         26.460        557.30

                                        ROTOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL     BLADE     Y=VA /VAM     BLADE         LOSS          ZETA*         FLOW RATE
 LINE    POSITION               SHIFT    OPENING                EFFICIENCY   COEFFICIENT    CONTINUITY     FRACTION

   1       2.693        .825    .0710     .1912       .9852       .8597         .1404          .1404          0.0000
   2       3.020        .925   -.0168     .2218       .9474       .6666         .1334          .1334          . .2301
   3       3.265       1.000   -.0405     .2447      1.0000       .8719         .1282          .1282           .4266
   4       3.585       1.098   -.1537     .2747      1.1020       .8786         .1214          .1214           .7217
   5       3.837       1.175   -.2190     .2983      1.2063       .8039         .1162          .1162          1.0000

                   ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY        VELOCITY

   1    275.35        -11.05       -310.15       414.89          275.36      -11.05      -662.66       717.68          352.51
   2    264.80          2.52       -212.98       339.84          264.80        2.52      -608.29       663.43          395.31
   3    279.51          6.40       -193.25       339.87          279.51        6.40      -620.64       680.71          427.39
   4    308.03         26.75       -174.77       355.17          308.03       26.75      -644.10       714.47          469.33
   5    337.17         40.00       -171.32       380.31          337.17       40.00      -673.59       754.32          502.26

            MACH NUMBER                  FLOW ANGLE               TEMPERATURE                PRESSURE                  PRESSURE
                                           (DEG)                    (DEG. R)                   (PSI)                     RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE         ABSOLUTE   RELATIVE         TOTAL      STATIC         TOTAL      STATIC         TOT/TOT      TOT/STA

   1        .39        .67           -48.40     -67.44           490.25     475.92         15.224     13.723         1.7381       1.9281
   2        .32        .62           -38.81     -66.48           493.32     483.71         15.823     14.771         1.6722       1.7914
   3        .32        .63           -34.66     -65.76           493.16     483.78         15.875     14.843         1.6668       1.7826
   4        .33        .66           -29.57     -64.45           493.10     482.61         15.932     14.777         1.6608       1.7907
   5        .35        .70           -26.94     -63.41           492.65     480.62         15.904     14.586         1.6637       1.8141

STREAM    EQUIVALENT     EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE    INLET          PRESSURE
                         PRESSURE        RATIO
           (DEG. R)      (PSI
  1         518.78        19.545          1.4
  2         520.34        19.868          1.3
  3         522.34        20.230          1.4
  4         525.08        20.721          1.4
  5         527.76        21.211          1.5
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   SET      PAGE       RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
 NUMBER   NUMBER               PRESSURE RATIO     PRESSURE      TEMPERATURE
                                                    (PSI)        (DEG. R)

    1        3     15000.0         1.800           26.460         557.30


                          OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO            EFFICIENCY              HEAD       BLADE/JET      THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       1.9281     1.7381       .7035        .8236        8.7505        .3381             .2309
  2       1.7914     1.6722       .7482        .8403        6.6497        .3878             .2367
  3       1.7826     1.6668       .7560        .8475        5.8274        .4142             .3059
  4       1.7907     1.6608       .7513        .8538        5.0891        .4433             .3963
  5       1.8141     1.6637       .7414        .8571        4.6491        .4638             .4730


                              MASS AVERAGED QUANTITIES


                              HORSE POWER =       76.87    (HP)
                              MOMENT      =       26.91    (FT-LB)
                              FLOW RATE   =        3.51    (LB/SEC)


                     REFERRED  RPM         =   14467.03
                     REFERRED HORSE POWER =       41.19    (HP)
                     REFERRED MOMENT      =       14.95    (FT-LB)
                     REFERRED FLOW RATE   =        2.02    (LB/SEC)


                 TOTAL/STATIC EFFICIENCY =        .7445
                 TOTAL/TOTAL  EFFICIENCY=         .8455
               TOTAL/STATIC PRESSURE RATIO =     1.8090
               TOTAL/TOTAL  PRESSURE RATIO =     1.6751


              HEAD COEFFICIENT               =   6.0665
              BLADE/JET SPEED RATIO          =    .4060
              THEORETICAL DEGREE OF REACTION=     .3227
              MACH NUMBER AT STATION 0       =    .2014
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                        SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                       NUMBER  NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
                         1       1      20000.0         1.000         26.460         557.30

                                                     STATOR EXIT SOLUTION

STREAM   RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS          ZETA*        FLOW RATE
 LINE   POSITION                SHIFT   OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

          (IN)                  (IN)     (IN)
  1      2.764        .865    0.0000     .2126       1.0996       .9040        .0952         .0952         0.0000
  2      3.003        .940    0.0000     .2347       1.0461       .9034        .0966         .0966          .2565
  3      3.195       1.000     .0290     .2526       1.0000       .9023        .0977         .0977          .4770
  4      3.432       1.074    0.0000     .2745        .9408       .9012        .0988         .0988          .7596
  5      3.627       1.135    0.0000     .2926        .8916       .9002        .0998         .0998         1.0000

                   ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY      COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

  1     352.31       -14.13        778.26       854.40        352.31      -14.13        295.85       460.27        482.41
  2     335.10         3.18        732.20       805.27        335.10        3.18        208.06       394.51        524.14
  3     329.48         7.33        693.70       764.16        329.48        7.33        135.98       356.51        557.72
  4     301.44        26.18        647.42       714.64        301.44       26.18         48.48       306.44        598.94
  5     285.67        33.89        609.50       673.98        285.67       33.89        -23.53       288.64        633.03

              MACH NUMBER               FLOW ANGLE               TEMPERATURE            PRESSURE              PRESSURE
                                          (DEG)                   (DEG. R)               (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE         TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1          .78        .42          65.65      40.02          557.30    496.56       25.287    16.384       1.0464     1.5672
  2          .73        .36          65.41      31.83          557.30    503.34       25.414    17.794       1.0412     1.4870
  3          .69        .32          65.21      22.43          557.30    508.71       25.515    18.541       1.0370     1.4271
  4          .64        .28          65.04       9.14          557.30    514.00       25.631    19.418       1.0323     1.3622
  5          .60        .26          64.89      -4.71          557.30    519.50       25.721    20.115       1.0287     1.3154
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         SET     PAGE         KPM       TOTAL/STATIC     INLET TOTAL   INLET TOTAL
       NUMBER   NUMBER                 PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                            (PSI)       (DEG. R)

          1        2     20000.0           1.800           26.460        557.30

                                            ROTOR EXIT SOLUTION

STREAM     RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS         ZETA*         FLOW RATE
 LINE     POSITION               SHIFT    OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

   1        2.693        .825     .0710    .1912        .9937       .8069        .1131        .1131        0.0000
   2        3.020        .925    -.0168    .2218        .9145       .8915        .1085        .1085         .2243
   3        3.265       1.000    -.0405    .2447       1.0000       .8950        .1050        .1050         .4169
   4        3.585       1.098    -.1537    .2747       1.1464       .8861        .1140        .1140         .7142
   5        3.837       1.175    -.2100    .2983       1.2882       .8790        .1210        .1210        1.0000

                  ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL      TANGENTIAL     OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT      COMPONENT     COMPONENT     VELOCITY      COMPONENT  COMPONENT    COMPONENT    VELOCITY      VELOCITY

   1    268.07        -10.75       -175.09        320.36        268.07     -10.75      -645.11       698.67        470.02
   2    246.71          2.34        -39.64        249.88        246.71       2.34      -566.72       618.09        527.07
   3    269.76          6.17        -29.15        271.40        269.76       6.17      -599.00       656.97        569.85
   4    309.25         25.86        -20.91        311.13        309.26      26.86      -646.68       717.33        625.77
   5    347.51         41.23        -24.56        350.81        347.51      41.23      -694.24       777.45        669.68

              MACH NUMBER               FLOW ANGLE               TEMPERATURE              PRESSURE                PRESSURE
                                          (DEG)                   (DEG. R)                 (PSI)                    RATIO
STREAM
 LINE     ABSOLUTE  RELATIVE       ABSOLUTE  RELATIVE         TOTAL     STATIC         TOTAL     STATIC        TOT/TOT    TOT/STA

   1         .30       .66          -33.15    -67.44          481.12    472.56         14.545    13.661         1.8191     1.9378
   2         .23       .57           -9.13    -65.48          489.95    484.76         15.744    15.168         1.6306     1.7445
   3         .25       .61           -6.17    -65.76          490.15    484.51         15.789    15.162         1.6759     1.7451
   4         .29       .67           -3.87    -64.45          490.59    482.53         15.759    14.871         1.6791     1.7772
   5         .33       .72           -4.04    -63.41          490.35    480.11         15.619    14.507         1.6940     1.8239

STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE     INLET         PRESSURE
                         PRESSURE        RATIO
           (DEG. R)       (PSI
  1        513.20         18.949          1.4
  2        516.55         19.483          1.3
  3        520.42         20.079          1.3
  4        525.35         20.846          1.4
  5        530.41         21.632          1.5
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          SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
         NUMBER  NUMBER              PRESSURE RATIO  PRESSURE      TEMPERATURE
                                                       (PSI)        (DEG. R)

           1       3     20000.0        1.800         26.460        557.30


                           OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO          EFFICIENCY          HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA    TOT/TOT  COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       1.9358     1.8191      .7943      .8699      4.9528        .4493          .3000
  2       1.7445     1.6806      .8221      .8766      3.5835        .5283          .2709
  3       1.7351     1.6759      .8193      .8785      3.1668        .5619          .3430
  4       1.7792     1.6791      .7887      .8698      2.8337        .5940          .4425
  5       1.8239     1.6940      .7614      .8593      2.6368        .6158          .5225


                                MASS AVERAGED QUANTITIES


                              HORSE POWER =       81.09    (HP)
                              MOMENT      =       21.30    (FT-LB)
                              FLOW RATE   =        3.51    (LB/SEC)


                    REFERRED  RPM         =  19289.37
                    REFERRED HORSE POWER =       43.45    (HP)
                    REFERRED MOMENT       =       11.83    (FT-LB)
                    REFERRED FLOW RATE    =        2.02    (LB/SEC)


                 TOTAL/STATIC EFFICIENCY =        .8020
                 TOTAL/TOTAL  EFFICIENCY=         .8724
              TOTAL/STATIC PRESSURE RATIO =      1.7873
              TOTAL/TOTAL  PRESSURE RATIO =      1.6980


             HEAD COEFFICIENT                =   3.3447
             BLADE/JET SPEED RATIO           =    .5468
             THEORETICAL DEGREE OF REACTION=      .3669
             MACH NUMBER AT STATION 0        =    .2015
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                     SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                    NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                      1        1      25000.0        1.800          26.460         557.30

                                              STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL    BLADE       Y=VA /VAM      BLADE        LOSS         ZETA*       FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY   FRACTION

           (IN)                  (IN)      (IN)
  1        2.764        .865    0.0000     .2126       1.1008       .9085        .0915        .0915       0.0000
  2        3.003        .940    0.0000     .2347       1.0466       .9064        .0936        .0936        .2567
  3        3.195       1.000     .0290     .2526       1.0000       .9047        .0953        .0953        .4772
  4        3.432       1.074    0.0000     .2745        .9404       .9032        .0968        .0968        .7598
  5        3.627       1.135    0.0000     .2926        .8909       .9019        .0981        .0981       1.0000

                    ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT     VELOCITY     VELOCITY

  1      353.56       -14.18       781.02       857.44       353.56      -14.18       178.01       396.09       603.01
  2      336.16         3.19       734.34       807.63       336.16        3.19        79.17       345.37       655.17
  3      330.62         7.35       695.41       766.04       330.62        7.35        -1.74       330.71       697.15
  4      302.05        26.23       648.72       716.07       302.05       26.23       -99.95       319.24       748.67
  5      286.15        33.95       610.53       675.11       286.15       33.95      -180.77       340.17       791.29

            MACH NUMBER                FLOW ANGLE             TEMPERATURE               PRESSURE                  PRESSURE
                                          (DEG)                 (DEG. R)                  (PSI)                     RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE       TOTAL     STATIC         TOTAL     STATIC         TOT/TOT    TOT/STA

  1         .79        .36          65.65      26.73        557.30    496.12         25.328    16.860         1.0447     1.5694
  2         .73        .31          65.41      13.25        557.30    503.02         25.443    17.775         1.0400     1.4886
  3         .69        .30          65.21       -.30        557.30    508.47         25.535    18.525         1.0362     1.4283
  4         .64        .29          65.04     -18.31        557.30    514.63         25.646    19.406         1.0317     1.3635
  5         .60        .30          64.89     -32.28        557.30    519.37         25.732    20.106         1.0283     1.3160
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      SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
    NUMBER   NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                    (PSI)        (DEG. R)

       1        2     25000.0        1.800         26.460        557.30

                                  ROTOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL     BLADE     Y=VA /VAM    BLADE        LOSS         ZETA*       FLOW RATE
 LINE   POSITION               SHIFT    OPENING              EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

   1      2.693       .825     .0710     .1912      1.0024      .9035        .0966         .0966        0.0000
   2      3.020       .925    -.0168     .2218       .8851      .8858        .1143         .1143         .2176
   3      3.265      1.000    -.0405     .2447      1.0000      .8725        .1275         .1275         .4048
   4      3.585      1.098    -.1537     .2747      1.1867      .8819        .1181         .1181         .7035
   5      3.837      1.175    -.2100     .2983      1.3613      .8893        .1108         .1108        1.0000

                 ABSOLUTE VELOCITY (FPS)                              RELATIVE VELOCITY (FPS)

STREAM   AXIAL     RADIAL     TANGENTIAL   OVERALL        AXIAL      RADIAL     TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT   COMPONENT   COMPONENT    VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

   1    269.51     -10.81      -61.06       276.55        269.51     -10.81      -648.58      702.43       587.52
   2    237.98       2.26      112.18       263.10        237.98       2.26      -546.66      596.22       658.84
   3    268.87       6.15      115.30       292.61        268.87       6.15      -597.01      654.79       712.31
   4    319.06      27.71      115.04       340.30        319.06      27.71      -667.17      740.06       782.21
   5    366.00      43.42      105.92       383.48        366.00      43.42      -731.19      818.83       837.11

              MACH NUMBER             FLOW ANGLE            TEMPERATURE            PRESSURE              PRESSURE
                                        (DEG)                (DEG. R)               (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE  RELATIVE      ABSOLUTE  RELATIVE       TOTAL    STATIC        TOTAL    STATIC       TOT/TOT    TOT/STA

   1         .26       .66         -12.77    -67.44        472.95   466.59        13.797   13.158       1.9178     2.0110
   2         .24       .55          25.24    -66.48        489.53   483.77        15.720   15.032       1.6832     1.7544
   3         .27       .61          23.21    -65.76        490.29   483.67        15.701   14.972       1.6853     1.7673
   4         .32       .69          19.83    -64.45        491.45   481.81        15.794   14.736       1.6753     1.7956
   5         .36       .76          16.14    -63.41        491.66   479.42        15.768   14.436       1.6781     1.8329

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE    TEMPERATURE    INLET        PRESSURE
                       PRESSURE        RATIO
          (DEG. R)      (PSI
   1      507.64       18.270          1.4
   2      513.35       19.085          1.3
   3      519.35       19.950          1.3
   4      527.38       21.142          1.4
   5      535.21       22.335          1.5
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      SET       PAGE        RPM       TOTAL/STATIC       INLET TOTAL     INLET TOTAL
     NUMBER    NUMBER               PRESSURE RATIO      PRESSURE       TEMPERATURE
                                                          (PSI)          (DEG. R)

       1          3      25000.0         1.800            26.460          557.30


                         OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO            EFFICIENCY             HEAD         BLADE/JET      THEORETICAL
 LINE     TOT/STA     TOT/TOT     TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO  DEGREE OF REACTION

   1      2.0110      1.9178       .8365        .8915       3.3326         .5478            .3322
   2      1.7544      1.6832       .8196        .8797       2.3150         .6572            .2758
   3      1.7673      1.6853       .8009        .8681       2.0690         .6952            .3550
   4      1.7956      1.6753       .7673        .8621       1.8400         .7372            .4495
   5      1.8329      1.6781       .7411        .8568       1.7001         .7669            .5253


                                    MASS AVERAGED QUANTITIES


                                   HORSE POWER =      81.93   (HP)
                                   MOMENT      =      17.21   (FT-LB)
                                   FLOW RATE   =       3.52   (LB/SEC)

                          REFERRED  RPM         =  24111.71
                          REFERRED  HORSE POWER =     43.90   (HP)
                          REFERRED  MOMENT      =      9.56   (FT-LB)
                          REFERRED  FLOW RATE   =      2.03   (LB/SEC)

                       TOTAL/STATIC EFFICIENCY =       .7941
                       TOTAL/TOTAL  EFFICIENCY=        .8710
                   TOTAL/STATIC PRESSURE RATIO =      1.8098
                   TOTAL/TOTAL  PRESSURE RATIO =      1.7105

                 HEAD COEFFICIENT              =      2.1851
                 BLADE/JET SPEED RATIO         =       .6765
                 THEORETICAL DEGREE OF REACTION=       .3773
                 MACH NUMBER AT STATION 0      =       .2022
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                          SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                         NUMBER  NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
                           1       1      30000.0        1.800          26.460          557.30

                                                          STATOR EXIT SOLUTION

STREAM     RADIAL        X=R/RM   RADIAL     BLADE     Y=VA /VAM      BLADE        LOSS          ZETA*        FLOW RATE
 LINE     POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

           (IN)                   (IN)     (IN)
  1        2.764          .865   0.0000     .2126     1.1018         .9124        .0876         .0076        0.0000
  2        3.003          .940   0.0000     .2347     1.0470         .9096        .0904         .0904         .2562
  3        3.195         1.000    .0290     .2526     1.0000         .9073        .0927         .0927         .4766
  4        3.432         1.074   0.0000     .2745      .9400         .9055        .0945         .0945         .7593
  5        3.627         1.135   0.0000     .2926      .8903         .9039        .0961         .0961        1.0000

                      ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL     OVERALL            AXIAL      RADIAL    TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT      VELOCITY         COMPONENT  COMPONENT   COMPONENT     VELOCITY       VELOCITY

  1     362.67        -14.55       801.15        879.53            362.67     -14.55        77.53       371.15         723.62
  2     344.62          3.27       752.84        827.97            344.62       3.27       -33.37       346.25         786.21
  3     335.37          7.53       712.63        785.01            335.37       7.53      -123.95       357.63         836.58
  4     309.41         26.87       664.52        733.51            309.41      26.87      -233.89       388.79         898.41
  5     293.04         34.77       625.22        691.36            293.04      34.77      -324.33       438.49         949.55

               MACH NUMBER              FLOW ANGLE             TEMPERATURE              PRESSURE                 PRESSURE
                                          (DEG)                 (DEG. R)                 (PSI)                     RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE      ABSOLUTE  RELATIVE       TOTAL     STATIC         TOTAL     STATIC         TOT/TOT     TOT/STA

  1           .81        .34          65.65     12.07        557.30    492.93         25.317    16.476         1.0452      1.6060
  2           .76        .32          65.41     -5.53        557.30    500.26         25.425    17.423         1.0407      1.5187
  3           .71        .32          65.21    -20.29        557.30    506.02         25.514    18.200         1.0371      1.4539
  4           .66        .35          65.04    -37.09        557.30    512.53         25.625    19.115         1.0326      1.3843
  5           .62        .39          64.89    -47.90        557.30    517.53         25.711    19.841         1.0291      1.3336
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   SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
  NUMBER  NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                  (PSI)       (DEG. R)

    1       2       30000.0        1.800         26.460        557.30

                                     ROTOR EXIT SOLUTION

STREAM   RADIAL     X=R/RM  RADIAL    BLADE    Y=VA /VAM   BLADE       LOSS        ZETA*      FLOW RATE
 LINE   POSITION            SHIFT    OPENING             EFFICIENCY COEFFICIENT  CONTINUITY   FRACTION

  1      2.693       .825    .0710    .1912     1.0116     .9130       .0070       .0070       0.0000
  2      3.020       .925   -.0168    .2218      .8541     .8930       .1070       .1070        .2084
  3      3.265      1.000   -.0405    .2447     1.0000     .8780       .1221       .1221        .3899
  4      3.585      1.098   -.1537    .2747     1.2331     .8875       .1125       .1125        .6913
  5      3.837      1.175   -.2100    .2983     1.4460     .8950       .1051       .1051       1.0000

                  ABSOLUTE VELOCITY (FPS)                              RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL    TANGENTIAL   OVERALL       AXIAL      RADIAL    TANGENTIAL   OVERALL       WHEEL
 LINE  COMPONENT   COMPONENT   COMPONENT    VELOCITY    COMPONENT  COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1     265.45      -10.65       66.22       273.79      265.45     -10.65     -638.81      691.85       705.03
  2     224.13        2.13      275.76       355.36      224.13       2.13     -514.85      561.52       790.61
  3     262.40        6.00      272.12       378.07      262.40       6.00     -582.66      639.05       854.78
  4     323.58       28.10      262.04       417.32      323.58      28.10     -676.61      750.53       938.65
  5     379.44       45.02      246.49       454.71      379.44      45.02     -758.03      848.89      1004.53

            MACH NUMBER             FLOW ANGLE           TEMPERATURE            PRESSURE             PRESSURE
                                      (DEG)               (DEG. R)               (PSI)                RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE     TOTAL     STATIC      TOTAL     STATIC      TOT/TOT    TOT/STA

  1         .26       .66         14.01    -67.44      468.59    462.35      13.407    12.793      1.9736     2.0683
  2         .33       .52         50.90    -66.48      495.08    484.57      16.422    15.234      1.6113     1.7369
  3         .35       .59         46.05    -65.76      496.79    485.24      16.490    15.186      1.6047     1.7424
  4         .39       .70         39.00    -64.45      498.88    484.39      16.656    15.023      1.5886     1.7613
  5         .42       .79         33.01    -63.41      499.71    482.50      16.671    14.747      1.5872     1.7942

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE    TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1       502.18        17.584        1.4
  2       510.81        18.744        1.2
  3       519.23        19.917        1.3
  4       531.26        21.673        1.4
  5       542.46        23.394        1.6
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                     SET     PAGE      RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                    NUMBER  NUMBER              PRESSURE RATIO   PRESSURE       TEMPERATURE
                                                                   (PSI)          (DEG. R)

                      1       3     30000.0         1.800          26.460          557.30


                                     OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO           EFFICIENCY            HEAD         BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA      TOT/TOT   COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.0683     1.9736       .8490        .9017      2.3981         .6457          .3248
  2       1.7369     1.6113       .7651        .8763      1.5811         .7953          .2288
  3       1.7424     1.6047       .7401        .8591      1.4037         .8440          .3087
  4       1.7613     1.5886       .7020        .8463      1.2390         .8984          .4058
  5       1.7942     1.5872       .6719        .8359      1.1425         .9356          .4867


                                          MASS AVERAGED QUANTITIES


                                        HORSE POWER =      75.08    (HP)
                                        MOMENT      =      13.14    (FT-LB)
                                        FLOW RATE   =       3.53    (LB/SEC)

                                REFERRED  RPM         =  28934.05
                                REFERRED HORSE POWER =     40.23    (HP)
                                REFERRED MOMENT      =      7.30    (FT-LB)
                                REFERRED FLOW RATE   =      2.03    (LB/SEC)

                            TOTAL/STATIC EFFICIENCY =       .7419
                             TOTAL/TOTAL  EFFICIENCY=       .8626
                        TOTAL/STATIC PRESSURE RATIO =     1.7930
                        TOTAL/TOTAL  PRESSURE RATIO =     1.6462

                      HEAD COEFFICIENT                =   1.4986
                      BLADE/JET SPEED RATIO           =    .8169
                      THEORETICAL DEGREE OF REACTION=      .3373
                      MACH NUMBER AT STATION 0        =    .2025
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                    SET       PAGE        RPM       TOTAL/STATIC      INLET TOTAL    INLET TOTAL
                   NUMBER    NUMBER              PRESSURE RATIO     PRESSURE      TEMPERATURE
                     1         1        5000.0        2.000          29.400          591.01

                                                         STATOR EXIT SOLUTION

STREAM     RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE        LOSS           ZETA*          FLOW RATE
 LINE     POSITION              SHIFT    OPENING                  EFFICIENCY   COEFFICIENT    CONTINUITY      FRACTION

           (IN)                  (IN)      (IN)
  1        2.764         .865   0.0000     .2126      1.1063        .9231         .0769          .0769          0.0000
  2        3.003         .940   0.0000     .2347      1.0488        .9158         .0842          .0842           .2493
  3        3.195        1.000    .0290     .2526      1.0000        .9100         .0900          .0900           .4668
  4        3.432        1.074   0.0000     .2745       .9385        .9046         .0954          .0954           .7518
  5        3.627        1.135   0.0000     .2926       .8879        .9001         .0999          .0999          1.0000

                  ABSOLUTE VELOCITY (FPS)                                      RELATIVE VELOCITY (FPS)

STREAM    AXIAL         RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL      TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT       COMPONENT    COMPONENT     VELOCITY        COMPONENT   COMPONENT    COMPONENT     VELOCITY        VELOCITY

  1     488.05         -19.58       1078.13      1183.62          488.05      -19.58       957.53       1074.92         120.60
  2     462.68           4.40       1010.73      1111.61          462.68        4.40       879.70        993.96         131.03
  3     447.96          10.09        955.11      1052.11          447.96       10.09       815.68        930.65         139.43
  4     414.01          35.96        889.19       981.51          414.01       35.96       739.46        848.23         149.73
  5     391.68          46.47        835.68       924.08          391.68       46.47       677.42        783.88         158.26

               MACH NUMBER                  FLOW ANGLE                TEMPERATURE                PRESSURE                  PRESSURE
                                              (DEG)                    (DEG. R)                   (PSI)                     RATIO
STREAM
 LINE      ABSOLUTE    RELATIVE        ABSOLUTE   RELATIVE          TOTAL      STATIC          TOTAL      STATIC         TOT/TOT     TOT/STA

  1          1.11        1.01           65.65      63.00           591.01      474.43          27.346     12.674         1.0751      2.3197
  2          1.03         .92           65.41      62.26           591.01      488.19          27.456     14.064         1.0708      2.0905
  3           .96         .85           65.21      61.23           591.01      498.90          27.564     15.234         1.0666      1.9299
  4           .89         .77           65.04      60.76           591.01      510.85          27.732     16.650         1.0601      1.7658
  5           .83         .70           64.89      59.97           591.01      519.95          27.869     17.800         1.0549      1.6517
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            SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
          NUMBER   NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                           (PSI)       (DEG. R)

             1        2       5000.0        2.000         29.400        591.01

                                        ROTOR EXIT SOLUTION

 STREAM   RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM    BLADE        LOSS         ZETA*         FLOW RATE
  LINE   POSITION               SHIFT    OPENING                EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

   1      2.693        .825    .0710      .1912       .9713       .7753        .2248        .2248        0.0000
   2      3.020        .925   -.0168      .2218      1.0055       .7718        .2282        .2282         .2393
   3      3.265       1.000   -.0405      .2447      1.0000       .7692        .2308        .2308         .4424
   4      3.585       1.098   -.1537      .2747      1.0194       .7655        .2345        .2345         .7357
  .5      3.837       1.175   -.2100      .2983      1.0538       .7627        .2374        .2374        1.0000

                ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

 STREAM    AXIAL      RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL     TANGENTIAL   OVERALL       WHEEL
  LINE  COMPONENT   COMPONENT    COMPONENT    VELOCITY    COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

   1     336.20      -13.49       -691.57      769.08      336.20      -13.49      -809.08      876.25       117.50
   2     348.06        3.31       -667.76      753.03      348.06        3.31      -799.53      872.01       131.77
   3     346.15        7.92       -626.16      715.52      346.15        7.92      -768.62      843.01       142.46
   4     352.86       30.65       -581.39      680.78      352.86       30.65      -737.84      818.44       156.44
   5     364.76       43.28       -561.29      670.80      364.76       43.28      -728.71      816.06       167.42

            MACH NUMBER              FLOW ANGLE             TEMPERATURE             PRESSURE               PRESSURE
                                       (DEG)                  (DEG. R)                (PSI)                  RATIO
 STREAM
  LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE       TOTAL     STATIC        TOTAL     STATIC       TOT/TOT    TOT/STA

   1         .70       .79        -64.08    -67.44        555.85    506.63        19.365    13.999       1.5182     2.1002
   2         .68       .79        -62.47    -66.48        554.33    507.14        19.235    14.088       1.5285     2.0869
   3         .65       .76        -61.07    -65.76        554.00    511.90        19.427    14.733       1.5133     1.9955
   4         .61       .74        -58.75    -64.45        553.71    515.15        19.619    15.238       1.4986     1.9294
   5         .60       .73        -56.99    -63.41        553.36    515.92        19.651    15.377       1.4961     1.9119

 STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
  LINE    TEMPERATURE    INLET        PRESSURE
                        PRESSURE       RATIO
           (DEG. R)      (PSI
   1       570.52       24.169          1.7
   2       570.41       24.250          1.7
   3       571.04       24.440          1.7
   4       570.89       24.566          1.6
   5       571.33       24.754          1.6
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   SET      PAGE       RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
  NUMBER   NUMBER               PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                    (PSI)        (DEG. R)

    1         3       5000.0        2.000          29.400         591.01

                         OVERALL TURBINE CHARACTERISTICS

STREAM     PRESSURE RATIO          EFFICIENCY           HEAD        BLADE/JET      THEORETICAL
 LINE    TOT/STA   TOT/TOT     TOT/STA      TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1      2.1002    1.5182       .3115        .5291     93.2818        .1035          -.1186
  2      2.0869    1.5285       .3274        .5437     78.4130        .1129          -.0021
  3      1.9955    1.5133       .3496        .5610     65.4437        .1236           .0439
  4      1.9294    1.4986       .3686        .5782     54.2298        .1358           .1241
  5      1.9119    1.4961       .3769        .5859     47.9336        .1444           .2098

                              MASS AVERAGED QUANTITIES

                              HORSE POWER =      50.34   (HP)
                              MOMENT      =      52.88   (FT-LB)
                              FLOW RATE   =       4.02   (LB/SEC)

                       REFERRED  RPM         =  4682.79
                       REFERRED HORSE POWER  =    23.58   (HP)
                       REFERRED MOMENT       =    26.44   (FT-LB)
                       REFERRED FLOW RATE    =     2.15   (LB/SEC)

                    TOTAL/STATIC EFFICIENCY =      .3475
                    TOTAL/TOTAL  EFFICIENCY=       .5601
                 TOTAL/STATIC PRESSURE RATIO =    2.0045
                 TOTAL/TOTAL  PRESSURE RATIO =    1.5119

               HEAD COEFFICIENT               =  67.1736
               BLADE/JET SPEED RATIO          =    .1220
               THEORETICAL DEGREE OF REACTION=     .0529
               MACH NUMBER AT STATION 0       =    .2146
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     SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
    NUMBER   NUMBER              PRESSURE RATIO     PRESSURE      TEMPERATURE
      1        1      10000.0         2.000          29.400           591.01

                                           STATOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE       LOSS        ZETA*        FLOW RATE
 LINE   POSITION              SHIFT    OPENING                 EFFICIENCY  COEFFICIENT  CONTINUITY     FRACTION

          (IN)                 (IN)     (IN)
  1      2.764        .865    0.0000    .2126       1.1048       .9122       .0878       .0878        0.0000
  2      3.003        .940    0.0000    .2347       1.0481       .9056       .0944       .0944         .2519
  3      3.195       1.000     .0290    .2526       1.0000       .9002       .0998       .0998         .4711
  4      3.432       1.074    0.0000    .2745        .9394       .8957       .1043       .1043         .7554
  5      3.627       1.135    0.0000    .2926        .8895       .8921       .1079       .1079        1.0000

                     ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL      TANGENTIAL    OVERALL          AXIAL      RADIAL      TANGENTIAL    OVERALL        WHEEL
 LINE   COMPONENT    COMPONENT    COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

  1      430.56      -17.27       951.13       1044.19          430.56     -17.27       709.93       830.47        241.21
  2      408.48        3.88       892.34        981.40          408.48       3.80       630.27       751.08        262.07
  3      394.59        8.92       843.80        929.50          394.59       8.92       564.94       689.16        278.86
  4      366.11       31.80       786.31        867.95          366.11      31.80       406.84       609.97        299.47
  5      346.65       41.13       739.61        817.85          346.65      41.13       423.09       540.51        316.52

              MACH NUMBER               FLOW ANGLE              TEMPERATURE              PRESSURE                PRESSURE
                                          (DEG)                   (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE        TOTAL     STATIC        TOTAL     STATIC        TOT/TOT    TOT/STA

  1          .95        .76          65.65      58.77         591.01    500.28        27.643    15.426        1.0636     1.9059
  2          .89        .68          65.41      57.06         591.01    510.86        27.750    16.663        1.0594     1.7644
  3          .83        .62          65.21      55.07         591.01    519.12        27.850    17.688        1.0557     1.6622
  4          .77        .54          65.04      53.06         591.01    528.32        28.003    18.914        1.0499     1.5544
  5          .72        .48          64.89      50.67         591.01    535.35        28.126    19.896        1.0453     1.4777
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      SET     PAGE          RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
     NUMBER  NUMBER                 PRESSURE RATIO    PRESSURE       TEMPERATURE
                                                        (PSI)         (DEG. R)

       1        2     10000.0          2.000          29.400          591.01

                                        ROTOR EXIT SOLUTION

STREAM   RADIAL      X=R/RM    RADIAL    BLADE     Y=VA /VAM    BLADE        LOSS        ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1       2.693        .825    .0710     .1912      .9767       .8273        .1727        .1727       0.0000
  2       3.020        .925   -.0168     .2218      .9818       .8274        .1726        .1726        .2366
  3       3.265       1.000   -.0405     .2447     1.0000       .8275        .1725        .1725        .4377
  4       3.585       1.098   -.1537     .2747     1.0531       .8322        .1678        .1678        .7312
  5       3.837       1.175   -.2100     .2983     1.1159       .8359        .1641        .1641       1.0000

             ABSOLUTE VELOCITY (FPS)                             RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT     VELOCITY     COMPONENT  COMPONENT    COMPONENT     VELOCITY     VELOCITY

  1     325.69       -13.06      -548.77       638.28        325.69     -13.06      -783.78       848.86       235.01
  2     327.40         3.11      -488.54       588.10        327.40       3.11      -752.07       820.25       263.54
  3     333.47         7.63      -455.53       564.59        333.47       7.63      -740.45       812.11       284.93
  4     351.18        30.50      -421.45       549.43        351.18      30.50      -734.33       814.56       312.08
  5     372.11        44.15      -408.55       554.38        372.11      44.15      -743.40       832.50       334.84

          MACH NUMBER               FLOW ANGLE             TEMPERATURE             PRESSURE               PRESSURE
                                      (DEG)                  (DEG. R)                (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1         .58        .78        -59.32     -67.44       531.37    497.47       17.424    13.833       1.6874     2.1253
  2         .54        .75        -56.18     -66.48       530.66    501.88       17.529    14.421       1.6772     2.0386
  3         .51        .74        -53.80     -65.76       530.25    504.04       17.580    14.722       1.6723     1.9970
  4         .50        .74        -50.28     -64.45       529.88    504.76       17.674    14.911       1.6634     1.9717
  5         .50        .76        -47.68     -63.41       529.28    503.71       17.655    14.846       1.6652     1.9804

STREAM   EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE     TEMPERATURE     INLET         PRESSURE
                        PRESSURE        RATIO
          (DEG. R)       (PSI
  1        557.43       22.524          1.6
  2        557.87       22.675          1.6
  3        558.92       22.907          1.6
  4        559.97       23.185          1.6
  5        561.38       23.492          1.6
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                   SET    PAGE      RPM      TOTAL/STATIC    INLET TOTAL  INLET TOTAL
                  NUMBER  NUMBER             PRESSURE RATIO   PRESSURE    TEMPERATURE
                                                                (PSI)       (DEG. R)

                    1       3    10000.0         2.000         29.400       591.01

                            .OVERALL TURBINE CHARACTERISTICS


 STREAM      PRESSURE RATIO          EFFICIENCY            HEAD        BLADE/JET      THEORETICAL
  LINE     TOT/STA    TOT/TOT    TOT/STA       TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

   1       2.1253     1.6874     .5208         .7269     23.6556        .2056          .1315
   2       2.0386     1.6772     .5545         .7434     19.0412        .2292          .1867
   3       1.9970     1.6723     .5734         .7525     16.3763        .2471          .2463
   4       1.9717     1.6634     .5867         .7644     13.9628        .2676          .3284
  .5       1.9804     1.6652     .5889         .7704     12.5727        .2820          .4047

                                     MASS AVERAGED QUANTITIES


                                HORSE POWER =      81.03    (HP)
                                MOMENT      =      42.56    (FT-LB)
                                FLOW RATE   =       3.93    (LB/SEC)


                          REFERRED  RPM         =   9365.59
                          REFERRED HORSE POWER =      37.95    (HP)
                          REFERRED MOMENT      =      21.28    (FT-LB)
                          REFERRED FLOW RATE   =       2.10    (LB/SEC)

                      TOTAL/STATIC EFFICIENCY =      .5674
                      TOTAL/TOTAL  EFFICIENCY=       .7522
                   TOTAL/STATIC PRESSURE RATIO =    2.0150
                   TOTAL/TOTAL  PRESSURE RATIO =    1.6723

                 HEAD COEFFICIENT              =   16.8736
                 BLADE/JET SPEED RATIO         =     .2434
                 THEORETICAL DEGREE OF REACTION=     .2574
                 MACH NUMBER AT STATION 0      =     .2093
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         SET      PAGE         RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
       NUMBER   NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
          1        1      15000.0         2.000           29.400         591.01


                                         STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM    RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS          ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING                   EFFICIENCY    COEFFICIENT    CONTINUITY     FRACTION

           (IN)                  (IN)      (IN)
  1        2.764       .865     0.0000     .2126      1.1015         .9061         .0939          .0939         0.0000
  2        3.003       .940     0.0000     .2347      1.0467         .9022         .0978          .0978          .2534
  3        3.195      1.000      .0290     .2526      1.0000         .8990         .1010          .1010          .4729
  4        3.432      1.074     0.0000     .2745       .9413         .8909         .1011          .1011          .7566
  5        3.627      1.135     0.0000     .2926       .8928         .8988         .1011          .1011         1.0000


                  ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL      TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT    COMPONENT     COMPONENT     VELOCITY      COMPONENT   COMPONENT    COMPONENT     VELOCITY       VELOCITY

  1     402.85      -16.16        889.91        976.98        402.85      -16.16       528.11        664.41         361.81
  2     382.80        3.64        836.24        919.70        382.80        3.64       443.13        585.59         393.10
  3     369.75        8.37        791.86        872.28        369.75        8.37       373.57        525.68         418.29
  4     344.25       29.90        739.37        816.13        344.25       29.90       290.16        451.22         449.20
  5     326.51       38.74        696.63        770.33        326.51       38.74       221.86        396.65         474.77


             MACH NUMBER               FLOW ANGLE              TEMPERATURE             PRESSURE                PRESSURE
                                         (DEG)                  (DEG. R)                (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE       TOTAL      STATIC       TOTAL      STATIC       TOT/TOT     TOT/STA

  1          .88        .60          65.65      52.67        591.01     511.58       27.778     16.762       1.0584      1.7539
  2          .82        .52          65.41      49.18        591.01     520.63       27.919     17.912       1.0531      1.6413
  3          .77        .47          65.21      45.30        591.01     527.70       28.036     18.857       1.0487      1.5591
  4          .72        .40          65.04      40.13        591.01     535.59       28.220     19.993       1.0418      1.4705
  5          .68        .35          64.89      34.20        591.01     541.63       28.358     20.896       1.0368      1.4070
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          SET      PAGE      RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
         NUMBER   NUMBER            PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                        (PSI)       (DEG. R)

           1        2      15000.0       2.000         29.400        591.01


                                        ROTOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS         ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

  1       2.693        .825    .0710     .1912      .9831       .8557       .1443        .1443        0.0000
  2       3.020        .925   -.0168     .2218      .9567       .8627       .1373        .1373         .2313
  3       3.265       1.000   -.0405     .2447     1.0000       .8680       .1320        .1320         .4293
  4       3.585       1.098   -.1537     .2747     1.0085       .8750       .1250        .1250         .7243
  5       3.837       1.175   -.2100     .2983     1.1810       .8805       .1195        .1195        1.0000

                 ABSOLUTE VELOCITY (FPS)                           RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL       AXIAL      RADIAL     TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT     COMPONENT     COMPONENT    VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1    312.83        -12.55       -400.31       508.20       312.83      -12.55      -752.83      815.33       352.51
  2    304.44          2.89       -304.04       430.27       304.44        2.89      -699.34      762.74       395.31
  3    318.22          7.28       -279.21       423.41       318.22        7.28      -706.60      774.98       427.39
  4    346.38         30.08       -254.97       431.15       346.38       30.08      -724.30      803.42       469.33
  5    375.82         44.59       -248.55       452.78       375.82       44.59      -750.81      840.81       502.26

           MACH NUMBER               FLOW ANGLE               TEMPERATURE             PRESSURE               PRESSURE
                                       (DEG)                    (DEG. R)                (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE       TOTAL     STATIC        TOTAL     STATIC       TOT/TOT    TOT/STA

  1         .47        .75         -52.00     -67.44        513.94    492.45        15.931    13.719       1.8455     2.1431
  2         .39        .70         -44.97     -66.48        516.30    500.89        16.478    14.821       1.7842     1.9847
  3         .39        .71         -41.27     -65.76        516.03    501.35        16.529    14.942       1.7787     1.9676
  4         .39        .73         -36.36     -64.45        515.82    500.35        16.604    14.926       1.7706     1.9697
  5         .41        .77         -33.48     -63.41        515.19    498.13        16.574    14.731       1.7739     1.9958


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE    TEMPERATURE   INLET         PRESSURE
                       PRESSURE        RATIO
          (DEG. R)     (PSI
  1       547.77        21.291          1.6
  2       549.31        21.610          1.5
  3       551.33        21.982          1.5
  4       554.07        22.513          1.5
  5       556.96        23.039          1.6
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                   SET     PAGE      RPM       TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                 NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                 (PSI)         (DEG. R)

                    1        3    15000.0         2.000         29.400         591.01

                                  OVERALL  TURBINE CHARACTERISTICS

STREAM       PRESSURE RATIO              EFFICIENCY              HEAD         BLADE/JET       THEORETICAL
 LINE     TOT/STA      TOT/TOT      TOT/STA        TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.1431       1.8455        .6664          .8120       10.6175         .3069            .2421
  2       1.9837       1.7842        .7112          .8292        8.1692         .3499            .2573
  3       1.9676       1.7787        .7216          .8363        7.1371         .3743            .3222
  4       1.9697       1.7706        .7225          .8447        6.1975         .4017            .4075
  5       1.9958       1.7739        .7160          .8493        5.6453         .4209            .4812

                                         MASS AVERAGED QUANTITIES

                                        HORSE POWER =        98.79     (HP)
                                        MOMENT      =        34.59     (FT-LB)
                                        FLOW RATE   =         3.86     (LB/SEC)

                               REFERRED  RPM         =   14048.38
                               REFERRED HORSE POWER =        46.26     (HP)
                               REFERRED MOMENT      =        17.29     (FT-LB)
                               REFERRED FLOW RATE   =         2.06     (LB/SEC)

                           TOTAL/STATIC EFFICIENCY =          .7116
                           TOTAL/TOTAL   EFFICIENCY=          .8352
                        TOTAL/STATIC PRESSURE RATIO =        1.9976
                        TOTAL/TOTAL  PRESSURE RATIO =        1.7858

                      HEAD COEFFICIENT                 =     7.4088
                      BLADE/JET SPEED RATIO            =      .3674
                      THEORETICAL DEGREE OF REACTION=         .3372
                      MACH NUMBER AT STATION 0         =      .2057
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                          SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                         NUMBER  NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                           1       1     20000.0         2.000          29.400         591.01


                                                        STATOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM     BLADE        LOSS         ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

           (IN)                 (IN)     (IN)
  1       2.764       .865    0.0000     .2126     1.1007      .9008        .0912        .0912       0.0000
  2       3.003       .940    0.0000     .2347     1.0465      .9064        .0936        .0936        .2543
  3       3.195      1.000     .0290     .2526     1.0000      .9045        .0955        .0955        .4742
  4       3.432      1.074    0.0000     .2745      .9406      .9034        .0966        .0966        .7576
  5       3.627      1.135    0.0000     .2926      .8914      .9024        .0976        .0976       1.0000


                    ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL     TANGENTIAL   OVERALL       WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT    VELOCITY    COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

  1     392.34       -15.74       866.69       951.49      392.34      -15.74       384.28      549.41       482.41
  2     373.02         3.54       814.87       896.20      373.02        3.54       290.73      472.95       524.14
  3     361.55         8.16       771.71       850.09      361.55        8.16       213.99      420.21       557.72
  4     335.27        29.12       720.07       794.83      335.27       29.12       121.13      357.67       598.94
  5     317.71        37.69       677.85       749.56      317.71       37.69        44.82      323.06       633.03


                MACH NUMBER              FLOW ANGLE              TEMPERATURE             PRESSURE                PRESSURE
                                           (DEG)                  (DEG. R)                (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE    RELATIVE      ABSOLUTE   RELATIVE       TOTAL      STATIC       TOTAL      STATIC       TOT/TOT     TOT/STA

  1          .85         .49          65.65      44.41        591.01     515.68       27.919     17.323       1.0530      1.6971
  2          .80         .42          65.41      37.94        591.01     524.10       28.068     18.442       1.0475      1.5942
  3          .75         .37          65.21      30.62        591.01     530.88       28.188     19.363       1.0430      1.5184
  4          .70         .31          65.04      19.87        591.01     538.44       28.339     20.455       1.0374      1.4373
  5          .66         .28          64.89       8.03        591.01     544.26       28.455     21.325       1.0332      1.3786
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           SET    PAGE       RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
          NUMBER  NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                       (PSI)        (DEG. R)

            1       2     20000.0        2.000         29.400        591.01


                                      ROTOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS         ZETA*        FLOW RATE
 LINE    POSITION               SHIFT   OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

   1       2.693        .825    .0710    .1912       .9898       .8838       .1162        .1162        0.0000
   2       3.020        .925   -.0168    .2218       .9301       .8890       .1110        .1110         .2267
   3       3.265       1.000   -.0405    .2447      1.0000       .8929       .1071        .1071         .4220
   4       3.585       1.098   -.1537    .2747      1.1264       .8880       .1121        .1121         .7188
  .5       3.837       1.175   -.2100    .2983      1.2511       .8841       .1159        .1159        1.0000

                  ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM     AXIAL       RADIAL    TANGENTIAL    OVERALL      AXIAL      RADIAL    TANGENTIAL   OVERALL      WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT    VELOCITY    COMPONENT   COMPONENT   COMPONENT   VELOCITY    VELOCITY

   1     307.44       -12.33      -269.85      409.26       307.44      -12.33     -739.87     801.30      470.02
   2     298.90         2.74      -136.58      319.57       288.90        2.74     -663.65     723.81      527.07
   3     310.61         7.11      -119.86      333.02       310.61        7.11     -689.71     756.46      569.85
   4     349.86        30.39      -105.81      366.78       349.86       30.39     -731.58     811.50      625.77
   5     388.62        46.11      -106.70      405.63       388.62       46.11     -776.38     869.44      669.68

              MACH NUMBER               FLOW ANGLE           TEMPERATURE           PRESSURE              PRESSURE
                                          (DEG)               (DEG. R)              (PSI)                 RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE  RELATIVE      TOTAL    STATIC      TOTAL    STATIC      TOT/TOT   TOT/STA

   1          .38       .74         -41.28    -67.44      500.32    486.38      14.010   13.416      1.9851    2.1914
   2          .29       .66         -25.30    -66.48      507.95    499.45      15.898   14.986      1.8493    1.9618
   3          .30       .69         -21.10    -65.76      508.01    499.09      15.942   14.984      1.8442    1.9621
   4          .34       .74         -16.83    -64.45      508.22    497.02      15.910   14.717      1.8479    1.9977
   5          .37       .80         -15.35    -63.41      507.71    494.01      15.762   14.324      1.8652    2.0525


STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE    INLET         PRESSURE
                         PRESSURE        RATIO
           (DEG. R)      (PSI
  1        539.81         20.331          1.5
  2        543.05         20.872          1.4
  3        546.71         21.460          1.4
  4        551.82         22.289          1.5
  5        556.92         23.112          1.6
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        SET      PAGE      RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
       NUMBER   NUMBER              PRESSURE RATIO     PRESSURE      TEMPERATURE
                                                        (PSI)         (DEG. R)

         1        3     20000.0         2.000          29.400         591.01


                         OVERALL TURBINE CHARACTERISTICS


 STREAM        PRESSURE RATIO            EFFICIENCY            HEAD        BLADE/JET      THEORETICAL
  LINE      TOT/STA    TOT/TOT      TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1        2.1914     1.9851        .7642        .8625       6.1204         .4039          .3015
   2        1.9618     1.8493        .8025        .8724       4.5275         .4700          .2876
   3        1.9621     1.8442        .8017        .8754       3.9997         .5000          .3578
   4        1.9977     1.8479        .7810        .8706       3.5516         .5306          .4511
  .5        2.0525     1.8652        .7590        .8640       3.2914         .5512          .5280


                               MASS AVERAGED QUANTITIES


                              HORSE POWER =    109.74   (HP)
                              MOMENT      =     28.82   (FT-LB)
                              FLOW RATE   =      3.85   (LB/SEC)


                       REFERRED  RPM        = 18731.18
                       REFERRED HORSE POWER =    51.39  (HP)
                       REFERRED MOMENT      =    14.41  (FT-LB)
                       REFERRED FLOW RATE   =     2.06  (LB/SEC)

                    TOTAL/STATIC EFFICIENCY =    .7067
                    TOTAL/TOTAL  EFFICIENCY=     .8704
                 TOTAL/STATIC PRESSURE RATIO =  2.0109
                 TOTAL/TOTAL  PRESSURE RATIO =  1.8666

               HEAD COEFFICIENT              =  4.1972
               BLADE/JET SPEED RATIO         =   .4881
               THEORETICAL DEGREE OF REACTION=   .3778
               MACH NUMBER AT STATION 0      =   .2052
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                          SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                        NUMBER   NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                           1        1      25000.0        2.000         29.400         591.01


                                                      STATOR EXIT SOLUTION


STREAM     RADIAL        X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE        LOSS          ZETA*        FLOW RATE
 LINE     POSITION                SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

            (IN)                   (IN)     (IN)
  1        2.764          .865    0.0000     .2126       1.1023        .9134        .0866         .0866        0.0000
  2        3.003          .940    0.0000     .2347       1.0472        .9101        .0899         .0899         .2553
  3        3.195         1.000     .0290     .2526       1.0000        .9075        .0925         .0925         .4754
  4        3.432         1.074    0.0000     .2745        .9401        .9058        .0942         .0942         .7584
  5        3.627         1.135    0.0000     .2926        .8904        .9044        .0956         .0956        1.0000


                     ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL    TANGENTIAL    OVERALL          AXIAL       RADIAL    TANGENTIAL    OVERALL          WHEEL
 LINE  COMPONENT     COMPONENT    COMPONENT    VELOCITY      COMPONENT    COMPONENT    COMPONENT    VELOCITY        VELOCITY

  1      386.00        -15.48       852.69       936.12         386.00      -15.48       249.68       459.98          603.01
  2      366.71          3.48       801.07       881.02         366.71        3.48       145.90       394.68          655.17
  3      350.19          8.01       758.19       835.20         350.19        8.01        61.04       355.56          697.15
  4      329.20         28.59       707.04       780.45         329.20       28.59       -41.63       333.05          748.67
  5      311.83         37.00       665.30       735.68         311.83       37.00      -125.99       338.35          791.29


              MACH NUMBER                FLOW ANGLE              TEMPERATURE              PRESSURE                 PRESSURE
                                           (DEG)                  (DEG. R)                 (PSI)                    RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE        ABSOLUTE   RELATIVE        TOTAL      STATIC        TOTAL      STATIC        TOT/TOT    TOT/STA

  1         .84        .41            65.65      32.90        591.01     518.09        28.049     17.691        1.0482     1.6619
  2         .78        .35            65.41      21.70        591.01     526.42        28.171     18.789        1.0436     1.5648
  3         .74        .31            65.21       9.89        591.01     532.97        28.273     19.690        1.0399     1.4932
  4         .68        .29            65.04      -7.21        591.01     540.33        28.408     20.757        1.0349     1.4164
  5         .64        .30            64.89     -22.00        591.01     545.97        28.512     21.605        1.0311     1.3608
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               SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
              NUMBER  NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                              (PSI)        (DEG. R)

                1        2     25000.0         2.000         29.400        591.01


                                                 ROTOR EXIT SOLUTION


 STREAM    RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM    BLADE        LOSS          ZETA*         FLOW RATE
  LINE    POSITION              SHIFT    OPENING               EFFICIENCY   COEFFICIENT    CONTINUITY      FRACTION

   1       2.693        .825    .0710     .1912       .9982       .9019        .0981         .0981          0.0000
   2       3.020        .925   -.0168     .2218       .9020       .8912        .1089         .1089           .2209
   3       3.265       1.000   -.0405     .2447      1.0000       .8831        .1170         .1170           .4114
   4       3.585       1.098   -.1537     .2747      1.1673       .8861        .1139         .1139           .7094
   5       3.837       1.175   -.2100     .2983      1.3260       .8885        .1115         .1115          1.0000

                      ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

 STREAM    AXIAL       RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL    TANGENTIAL    OVERALL         WHEEL
  LINE COMPONENT     COMPONENT    COMPONENT    VELOCITY    COMPONENT   COMPONENT  COMPONENT     VELOCITY       VELOCITY

   1    300.44        -12.05      -135.50      329.81       300.44      -12.05     -723.03      783.06          587.52
   2    271.49          2.58        35.19      273.78       271.49        2.58     -623.66      680.19          658.84
   3    301.00          6.89        43.96      304.27       301.00        6.89     -668.36      733.04          712.31
   4    351.34         30.51        47.55      355.85       351.34       30.51     -734.67      814.93          782.21
   5    399.12         47.35        39.75      403.88       399.12       47.35     -797.35      892.92          837.11

             MACH NUMBER              FLOW ANGLE             TEMPERATURE             PRESSURE               PRESSURE
                                        (DEG)                 (DEG. R)                (PSI)                   RATIO
 STREAM
  LINE     ABSOLUTE   RELATIVE    ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT     TOT/STA

   1          .31        .73       -24.28     -67.44      492.19     483.14      14.198    13.305       2.0707      2.2097
   2          .25        .62         7.39     -66.48      507.52     501.28      15.995    15.318       1.8381      1.9194
   3          .28        .67         8.31     -65.76      508.25     500.55      15.995    15.162       1.8381      1.9350
   4          .33        .74         7.71     -64.45      509.10     498.57      16.028    14.896       1.8343      1.9737
   5          .37        .82         5.69     -63.41      508.94     495.36      15.922    14.484       1.8465      2.0298


 STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE     TEMPERATURE   INLET        PRESSURE
                        PRESSURE      RATIO
           (DEG. R)     (PSI
   1       534.16        19.687        1.5
   2       539.78        20.512        1.3
   3       545.26        21.326        1.4
   4       553.83        22.629        1.5
   5       561.71        23.864        1.6
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          SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
        NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                        (PSI)        (DEG. R)

           1        3     25000.0         2.000         29.400        591.01

                      . OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO         EFFICIENCY           HEAD        BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT    TOT/STA     TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       2.2097     2.0707      .8249       .8905      3.9591        .5026          .3335
  2       1.9194     1.8381      .8312       .8850      2.8121        .5963          .2934
  3       1.9390     1.8381      .8124       .8772      2.5189        .6301          .3721
  4       1.9737     1.8343      .7850       .8708      2.2371        .6686          .4637
 .5       2.0298     1.8465      .7584       .8640      2.0771        .6939          .5399

                                  MASS AVERAGED QUANTITIES

                                HORSE POWER =     108.40    (HP)
                                MOMENT      =      22.79    (FT-LB)
                                FLOW RATE   =       3.79    (LB/SEC)

                         REFERRED  RPM          =  23413.97
                         REFERRED HORSE POWER =     50.80    (HP)
                         REFERRED MOMENT      =     11.40    (FT-LB)
                         REFERRED FLOW RATE   =      2.02    (LB/SEC)

                     TOTAL/STATIC EFFICIENCY =      .8051
                      TOTAL/TOTAL   EFFICIENCY=      .8776
                 TOTAL/STATIC PRESSURE RATIO =     1.9879
                  TOTAL/TOTAL  PRESSURE RATIO =     1.8673

               HEAD COEFFICIENT                =    2.6465
               BLADE/JET SPEED RATIO           =     .6147
               THEORETICAL DEGREE OF REACTION=      .3915
               MACH NUMBER AT STATION 0        =     .2016
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                          SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                         NUMBER  NUMBER             PRESSURE RATIO    PRESSURE     TEMPERATURE
                           1       1      30000.0        2.000          29.400          591.01


                                                           STATOR EXIT SOLUTION


STREAM    RADIAL        X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE       LOSS         ZETA*        FLOW RATE
 LINE    POSITION                 SHIFT   OPENING               EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

           (IN)                   (IN)     (IN)
  1        2.764         .865    0.0000    .2126       1.1043       .9201       .0799        .0799        0.0000
  2        3.003         .940    0.0000    .2347       1.0480       .9156       .0844        .0844         .2548
  3        3.195        1.000     .0290    .2526       1.0000       .9119       .0881        .0881         .4748
  4        3.432        1.074    0.0000    .2745        .9393       .9095       .0905        .0905         .7580
  5        3.627        1.135    0.0000    .2926        .8893       .9075       .0925        .0925        1.0000


                     ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT    COMPONENT     VELOCITY      VELOCITY

  1     397.01       -15.93       877.02        962.83       397.01      -15.93       153.40        425.92        723.62
  2     376.77         3.58       823.06        905.21       376.77        3.58        36.85        378.59        786.21
  3     352.11         8.23       778.40        857.45       352.11        8.23       -58.10        356.98        836.58
  4     337.72        29.33       725.33        800.63       337.72       29.33      -173.08        380.62        898.41
  5     319.71        37.93       682.12        754.28       319.71       37.93      -267.43        418.53        949.55


               MACH NUMBER              FLOW ANGLE              TEMPERATURE            PRESSURE              PRESSURE
                                          (DEG)                   (DEG. R)               (PSI)                 RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE      ABSOLUTE  RELATIVE        TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1           .87        .38          65.65     21.13         591.01    513.87       28.080    17.211       1.0470     1.7082
  2           .81        .34          65.41      5.59         591.01    522.83       28.181    18.349       1.0433     1.6022
  3           .76        .32          65.21     -9.38         591.01    529.83       28.268    19.284       1.0400     1.5246
  4           .70        .33          65.04    -27.14         591.01    537.67       28.397    20.394       1.0353     1.4416
  5           .66        .37          64.89    -39.91         591.01    543.67       28.497    21.276       1.0317     1.3819
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                          SET     PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                         NUMBER  NUMBER               PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                                         (PSI)        (DEG. R)

                           1       2      30000.0         2.000         29.400        591.01

                                                           ROTOR EXIT SOLUTION

 STREAM     RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS        ZETA*      FLOW RATE
  LINE     POSITION              SHIFT    OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

   1        2.693        .825     .0710    .1912     1.0060      .9114       .0886        .0886       0.0000
   2        3.020        .925    -.0168    .2218      .8756      .8932       .1069        .1069        .2130
   3        3.265       1.000    -.0405    .2447     1.0000      .8795       .1206        .1206        .3983
   4        3.585       1.098    -.1537    .2747     1.2080      .8912       .1089        .1089        .6982
   5        3.837       1.175    -.2100    .2983     1.4017      .9004       .0997        .0997       1.0000

                   ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

 STREAM     AXIAL        RADIAL      TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL   OVERALL        WHEEL
  LINE COMPONENT       COMPONENT     COMPONENT     VELOCITY       COMPONENT   COMPONENT    COMPONENT    VELOCITY       VELOCITY

   1     297.96         -11.95        -12.01        298.44          297.96      -11.95      -717.04      776.57         705.03
   2     259.34           2.46        194.87        324.40          259.34        2.46      -595.75      649.75         790.61
   3     296.19           6.78        197.09        355.84          296.19        6.78      -657.69      721.34         854.78
   4     357.80          31.08        190.49        406.53          357.80       31.08      -748.16      829.90         938.65
   5     415.16          49.26        175.12        453.27          415.16       49.26      -829.40      928.81        1004.53

             MACH NUMBER                FLOW ANGLE              TEMPERATURE              PRESSURE               PRESSURE
                                          (DEG)                  (DEG. R)                 (PSI)                  RATIO
 STREAM
  LINE    ABSOLUTE  RELATIVE        ABSOLUTE  RELATIVE         TOTAL    STATIC         TOTAL    STATIC        TOT/TOT    TOT/STA

   1         .28       .73           -2.31     -67.44          483.98   476.57         13.461   12.753        2.1041     2.3053
   2         .30       .59           36.92     -66.48          508.96   500.20         16.215   15.260        1.8131     1.9267
   3         .32       .66           33.64     -65.76          510.67   499.70         16.257   15.067        1.8084     1.9513
   4         .37       .76           28.03     -64.45          512.32   498.57         16.390   14.981        1.7938     1.9730
   5         .42       .85           22.87     -63.41          512.49   495.40         16.351   14.520        1.7981     2.0248

 STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
 LINE     TEMPERATURE   INLET        PRESSURE
                        PRESSURE      RATIO
           (DEG. R)     (PSI
   1        526.75       18.769        1.5
   2        535.33       19.932        1.3
   3        543.00       21.014        1.4
   4        555.88       22.915        1.5
   5        567.18       24.675        1.7
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     SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
   NUMBER   NUMBER             PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                   (PSI)         (DEG. R)

      1        3     30000.0        2.000          29.400         591.01

                          OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO          EFFICIENCY            HEAD        BLADE/JET    THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA     TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       2.3053     2.1841      .8531       .9053       2.8795        .5893         .3317
  2       1.9267     1.8131      .8126       .8880       1.9632        .7137         .2625
  3       1.9513     1.8084      .7819       .8730       1.7644        .7528         .3471
  4       1.9730     1.7938      .7545       .8660       1.5528        .8025         .4377
  5       2.0248     1.7981      .7278       .8608       1.4379        .8339         .5164

                                 MASS AVERAGED QUANTITIES

                                HORSE POWER =      105.42    (HP)
                                MOMENT      =       18.46    (FT-LB)
                                FLOW RATE   =        3.75    (LB/SEC)

                         REFERRED  RPM         =  28096.77
                         REFERRED HORSE POWER  =     49.37   (HP)
                         REFERRED MOMENT       =      9.23   (FT-LB)
                         REFERRED FLOW RATE    =      2.00   (LB/SEC)

                      TOTAL/STATIC EFFICIENCY =      .7849
                       TOTAL/TOTAL  EFFICIENCY=      .8775
                   TOTAL/STATIC PRESSURE RATIO =    2.0040
                   TOTAL/TOTAL  PRESSURE RATIO =    1.8516

                 HEAD COEFFICIENT               =   1.8598
                 BLADE/JET SPEED RATIO          =    .7333
                 THEORETICAL DEGREE OF REACTION=     .3678
                 MACH NUMBER AT STATION 0       =    .1995
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           SET      PAGE       RPM       TOTAL/STATIC     INLET TOTAL   INLET TOTAL
         NUMBER   NUMBER                PRESSURE RATIO   PRESSURE      TEMPERATURE
            1        1     15000.0          2.200          32.340         603.60

                                              STATOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM    RADIAL     BLADE     Y=VA /VAM      BLADE        LOSS         ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

            (IN)                (IN)      (IN)
  1        2.764      .865     0.0000     .2126      1.1032        .9106         .0894        .0894         0.0000
  2        3.003      .940     0.0000     .2347      1.0473        .9052         .0948        .0948          .2520
  3        3.195     1.000      .0290     .2526      1.0000        .9008         .0992        .0992          .4710
  4        3.432     1.074     0.0000     .2745       .9408        .9002         .0998        .0998          .7552
  5        3.627     1.135     0.0000     .2926       .8920        .8996         .1004        .1004         1.0000

                  ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL      TANGENTIAL    OVERALL          AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT     COMPONENT     VELOCITY       COMPONENT  COMPONENT    COMPONENT    VELOCITY      VELOCITY

  1     427.56       -17.15        944.51       1036.92          427.56     -17.15       502.70       722.94         361.81
  2     405.92         3.86        886.73        975.24          405.92       3.86       493.63       639.11         393.10
  3     387.58         8.87        839.15        924.37          307.58       8.87       420.86       572.20         418.29
  4     364.63        31.67        783.13        864.44          364.63      31.67       333.93       495.44         449.20
  5     345.74        41.02        737.65        815.69          345.74      41.02       262.88       436.26         474.77

               MACH NUMBER               FLOW ANGLE              TEMPERATURE              PRESSURE                PRESSURE
                                            (DEG)                  (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE        TOTAL     STATIC         TOTAL     STATIC        TOT/TOT     TOT/STA

  1          .93        .65           65.65      53.73         603.60    514.13         30.446    17.365         1.0622      1.8624
  2          .87        .57           65.41      50.57         603.60    524.46         30.586    18.702         1.0574      1.7292
  3          .82        .51           65.21      47.36         603.60    532.50         30.707    19.803         1.0532      1.6331
  4          .76        .43           65.04      42.49         603.60    541.42         30.921    21.135         1.0459      1.5302
  5          .71        .38           64.89      37.25         603.60    540.24         31.082    22.196         1.0405      1.4570
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        SET    PAGE       RPM       TOTAL/STATIC    INLET TOTAL   INLET TOTAL
      NUMBER  NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                      (PSI)        (DEG. R)

         1       2     15000.0          2.200         32.340         603.60

                                        ROTOR EXIT SOLUTION

STREAM    RADIAL     X=R/RM    RADIAL    BLADE     Y=VA /VAM      BLADE        LOSS        ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

   1      2.693       .825     .0710     .1912       .9817        .8565        .1436       .1436        0.0000
   2      3.020       .925    -.0168     .2218       .9631        .8624        .1376       .1376         .2317
   3      3.265      1.000    -.0405     .2447      1.0000        .8669        .1331       .1331         .4304
   4      3.585      1.098    -.1537     .2747      1.0807        .8754        .1247       .1247         .7254
   5      3.837      1.175    -.2100     .2983      1.1669        .8820        .1180       .1180        1.0000

                      ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM     AXIAL       RADIAL    TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT     VELOCITY     VELOCITY

   1    340.83       -13.67      -467.70       578.87        340.83     -13.67      -820.21       888.31       352.51
   2    334.38         3.18      -372.80       500.80        334.38       3.18      -768.11       837.74       395.31
   3    347.19         7.94      -343.55       488.50        347.19       7.94      -770.93       845.55       427.39
   4    375.22        32.59      -315.28       491.18        375.22      32.59      -784.61       870.33       469.33
   5    405.14        48.07      -307.12       510.66        405.14      48.07      -809.38       906.39       502.26

            MACH NUMBER              FLOW ANGLE              TEMPERATURE              PRESSURE               PRESSURE
                                       (DEG)                  (DEG. R)                 (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE      TOTAL     STATIC        TOTAL     STATIC        TOT/TOT    TOT/STA

   1        .53        .82         -53.92     -67.44       519.29    491.41       16.612    13.694        1.9468     2.3617
   2        .46        .76         -48.11     -66.48       521.06    500.19       17.117    14.835        1.8893     2.1799
   3        .45        .77         -44.70     -65.76       520.75    500.89       17.172    14.988        1.8833     2.1578
   4        .45        .79         -40.04     -64.45       520.43    500.35       17.274    15.052        1.8722     2.1486
   5        .47        .83         -37.17     -63.41       519.64    497.94       17.246    14.854        1.8752     2.1772


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1       557.07        22.993        1.7
  2       558.59        23.320        1.6
  3       560.38        23.676        1.6
  4       563.38        24.291        1.6
  5       566.31        24.864        1.7
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                      SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                     NUMBER  NUMBER              PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                                    (PSI)         (DEG. R)

                        1       3     15000.0         2.200         32.340         603.60


                                      OVERALL TURBINE CHARACTERISTICS


 STREAM      PRESSURE RATIO            EFFICIENCY             HEAD         BLADE/JET     THEORETICAL
  LINE     TOT/STA    TOT/TOT      TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1       2.3617     1.9468       .6416        .8059       12.0635         .2879            .2523
   2       2.1799     1.8893       .6851        .8227        9.3694         .3267            .2743
   3       2.1578     1.8833       .6958        .8297        8.1781         .3497            .3371
   4       2.1486     1.8722       .7020        .8400        7.0560         .3765            .4170
   5       2.1772     1.8752       .6979        .8460        6.4139         .3949            .4884


                                          MASS AVERAGED QUANTITIES


                                       HORSE POWER =     118.32    (HP)
                                       MOMENT      =      41.43    (FT-LB)
                                       FLOW RATE   =       4.19    (LB/SEC)


                                 REFERRED  RPM         =  13901.10
                                 REFERRED HORSE POWER  =     49.84    (HP)
                                 REFERRED MOMENT       =     18.83    (FT-LB)
                                 REFERRED FLOW RATE    =      2.05    (LB/SEC)


                            TOTAL/STATIC EFFICIENCY =      .6882
                            TOTAL/TOTAL  EFFICIENCY=       .8296
                         TOTAL/STATIC PRESSURE RATIO =    2.1889
                         TOTAL/TOTAL  PRESSURE RATIO =    1.8090


                      HEAD COEFFICIENT                 =     8.4606
                      BLADE/JET SPEED RATIO            =      .3438
                      THEORETICAL DEGREE OF REACTION=         .3497
                      MACH NUMBER AT STATION 0         =      .2049
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    SET     PAGE       RPM     TOTAL/STATIC     INLET TOTAL   INLET TOTAL
  NUMBER   NUMBER            PRESSURE RATIO   PRESSURE      TEMPERATURE
     1        1     20000.0       2.200          32.340         603.60


                                                STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS           ZETA*          FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT    CONTINUITY      FRACTION

           (IN)                  (IN)      (IN)
   1      2.764         .865    0.0000     .2126      1.1014        .9111         .0889          .0889          0.0000
   2      3.003         .940    0.0000     .2347      1.0468        .9081         .0919          .0919           .2530
   3      3.195        1.000     .0290     .2526      1.0000        .9057         .0943          .0943           .4724
   4      3.432        1.074    0.0000     .2745       .9405        .9045         .0955          .0955           .7564
   5      3.627        1.135    0.0000     .2926       .8912        .9035         .0965          .0965          1.0000


                    ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL      TANGENTIAL     OVERALL          AXIAL      RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT      COMPONENT     COMPONENT      VELOCITY       COMPONENT   COMPONENT   COMPONENT     VELOCITY        VELOCITY

   1     414.03       -16.61        914.61        1004.10         414.03      -16.61      432.20        590.75          482.41
   2     393.50         3.74        859.60         945.39         393.50        3.74      335.46        517.10          524.14
   3     381.15         8.60        813.88         896.54         381.15        8.60      256.16        459.31          557.72
   4     353.54        30.71        759.31         838.14         353.54       30.71      160.37        389.42          598.94
   5     335.01        39.75        714.75         790.37         335.01       39.75       81.72        347.11          633.03


               MACH NUMBER              FLOW ANGLE               TEMPERATURE              PRESSURE              PRESSURE
                                          (DEG)                    (DEG. R)                (PSI)                  RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE         TOTAL     STATIC        TOTAL     STATIC       TOT/TOT    TOT/STA

   1          .90        .54          65.65      46.23          603.60    519.70        30.592    18.119       1.0572     1.7849
   2          .84        .46          65.41      40.45          603.60    529.23        30.759    19.413       1.0514     1.6659
   3          .79        .40          65.21      33.91          603.60    536.72        30.896    20.483       1.0467     1.5269
   4          .73        .34          65.04      24.40          603.60    545.15        31.077    21.757       1.0407     1.4864
   5          .69        .30          64.89      13.71          603.60    551.62        31.215    22.776       1.0360     1.4199
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   SET     PAGE       RPM      TOTAL/STATIC      INLET TOTAL    INLET TOTAL
 NUMBER   NUMBER              PRESSURE RATIO       PRESSURE      TEMPERATURE
                                                     (PSI)        (DEG. R)

    1        2     20000.0        2.200            32.340         603.60


                                   ROTOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM    RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS          ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING                EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

   1      2.693        .825     .0710     .1912       .9876       .8852         .1148         .1148        0.0000
   2      3.020        .925   -.0168     .2218       .9391       .8896         .1104         .1104         .2272
   3      3.265       1.000   -.0405     .2447      1.0000       .8929         .1071         .1071         .4235
   4      3.585       1.098   -.1537     .2747      1.1131       .8986         .1014         .1014         .7201
  .5      3.837       1.175   -.2100     .2983      1.2264       .9030         .0970         .0970        1.0000

                  ABSOLUTE VELOCITY (FPS)                                     RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL      TANGENTIAL     OVERALL          AXIAL       RADIAL      TANGENTIAL     OVERALL        WHEEL
 LINE COMPONENT      COMPONENT     COMPONENT     VELOCITY       COMPONENT    COMPONENT     COMPONENT     VELOCITY       VELOCITY

   1    338.22        -13.57      -343.92       482.56          338.22       -13.57       -813.94       881.52        470.02
   2    321.59          3.06      -211.66       385.01          321.59         3.06       -738.74       805.71        527.07
   3    342.46          7.84      -190.57       391.99          342.46         7.84       -760.42       834.01        569.85
   4    381.20         33.11      -171.35       419.25          381.20        33.11       -797.11       884.20        625.77
   5    419.97         49.83      -169.33       455.56          419.97        49.83       -839.02       939.58        669.68

              MACH NUMBER                 FLOW ANGLE              TEMPERATURE               PRESSURE                PRESSURE
                                            (DEG)                  (DEG. R)                  (PSI)                    RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE        TOTAL      STATIC         TOTAL      STATIC        TOT/TOT      TOT/STA

   1         .45        .82          -45.48     -67.44         503.27     483.89        15.230     13.274        2.1235       2.4363
   2         .35        .74          -33.35     -66.48         510.05     497.72        16.270     14.934        1.9877       2.1655
   3         .36        .76          -29.10     -65.76         509.98     497.53        16.307     14.955        1.9832       2.1625
   4         .38        .81          -24.20     -64.45         510.07     495.44        16.361     14.777        1.9766       2.1885
   5         .42        .86          -21.96     -63.41         509.43     492.16        16.291     14.439        1.9851       2.2398


STREAM   EQUIVALENT    EQUIVALENT     EQUIV/STATIC
LINE     TEMPERATURE     INLET          PRESSURE
                        PRESSURE          RATIO
          (DEG. R)       (PSI
   1       548.55        21.890            1.6
   2       551.73        22.460            1.5
   3       555.41        23.090            1.5
   4       560.50        23.979            1.6
   5       565.62        24.864            1.7
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     SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
   NUMBER   NUMBER             PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                  (PSI)         (DEG. R)

      1        3     20000.0        2.200         32.340          603.60


                              OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO             EFFICIENCY          HEAD         BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT      TOT/STA       TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.4363     2.1235        .7400         .8587      7.0014         .3779          .3208
  2       2.1655     1.9877        .7824         .8697      5.2302         .4373          .3150
  3       2.1625     1.9832        .7842         .8729      4.6118         .4657          .3814
  4       2.1885     1.9766        .7728         .8759      4.0543         .4966          .4660
  5       2.2398     1.9851        .7582         .8770      3.7248         .5181          .5368


                                   MASS AVERAGED QUANTITIES

                                HORSE POWER =     136.30   (HP)
                                MOMENT      =      35.79   (FT-LB)
                                FLOW RATE   =       4.25   (LB/SEC)

                         REFERRED  RPM        =  18534.80
                         REFERRED HORSE POWER =     57.42  (HP)
                         REFERRED MOMENT      =     16.27  (FT-LB)
                         REFERRED FLOW RATE   =      2.09  (LB/SEC)

                      TOTAL/STATIC EFFICIENCY =       .7722
                       TOTAL/TOTAL  EFFICIENCY=       .8716
                   TOTAL/STATIC PRESSURE RATIO =     2.2137
                   TOTAL/TOTAL  PRESSURE RATIO =     2.0005

                 HEAD COEFFICIENT              =     4.8149
                 BLADE/JET SPEED RATIO         =      .4557
                 THEORETICAL DEGREE OF REACTION=      .3978
                 MACH NUMBER AT STATION 0    . =      .2082
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     SET     PAGE       RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
   NUMBER   NUMBER            PRESSURE RATIO   PRESSURE     TEMPERATURE
     1        1     25000.0        2.200        32.340         603.60


                                             STATOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL     BLADE      Y=VA /VAM     BLADE          LOSS         ZETA*         FLOW RATE
 LINE    POSITION              SHIFT    OPENING                 EFFICIENCY    COEFFICIENT    CONTINUITY     FRACTION

           (IN)                 (IN)     (IN)
  1        2.764       .865   0.0000     .2126     1.1029       .9153          .0847         .0847          0.0000
  2        3.003       .940   0.0000     .2347     1.0474       .9115          .0885         .0885           .2543
  3        3.195      1.000    .0290     .2526     1.0000       .9004          .0916         .0916           .4741
  4        3.432      1.074   0.0000     .2745      .9399       .9067          .0933         .0933           .7525
  5        3.627      1.135   0.0000     .2926      .8903       .9053          .0947         .0947          1.0000


                      ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL      TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT    COMPONENT     COMPONENT     VELOCITY       COMPONENT    COMPONENT   COMPONENT     VELOCITY        VELOCITY

  1     403.36      -16.18        891.04        978.22         403.36      -16.18       288.03        495.90          603.01
  2     383.07        3.64        836.81        920.33         383.07        3.64       181.64        423.97          655.17
  3     365.73        8.37        791.85        872.27         365.73        8.37        94.70        377.89          697.15
  4     343.77       29.86        738.33        814.99         343.77       29.86       -10.34        345.22          748.67
  5     325.61       38.63        694.71        768.20         325.61       38.63       -96.58        341.82          791.29


              MACH NUMBER               FLOW ANGLE              TEMPERATURE              PRESSURE              PRESSURE
                                          (DEG)                   (DEG. R)                 (PSI)                 RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE        TOTAL      STATIC        TOTAL     STATIC        TOT/TOT    TOT/STA

  1           .87        .44          65.65      35.53         603.60     523.97        30.776    18.757         1.0508     1.7241
  2           .81        .37          65.41      25.37         603.60     533.12        30.910    20.015         1.0463     1.6158
  3           .77        .33          65.21      14.52         603.60     540.29        31.023    21.050         1.0425     1.5364
  4           .71        .30          65.04      -1.72         603.60     548.33        31.181    22.280         1.0372     1.4515
  5           .67        .30          64.89     -16.52         603.60     554.49        31.303    23.260         1.0331     1.3904
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                             SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                            NUMBER  NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                                            (PSI)        (DEG. R)

                              1       2     25000.0         2.200          32.340        603.60


                                                    ROTOR EXIT SOLUTION


STREAM   RADIAL     X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS        ZETA*        FLOW RATE
 LINE    POSITION            SHIFT    OPENING              EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

  1       2.693      .825     .0710    .1912      .9947      .9031       .0969        .0969       0.0000
  2       3.020      .925   -.0168    .2218      .9138      .9049       .0951        .0951        .2227
  3       3.265     1.000   -.0405    .2447     1.0000      .9062       .0938        .0938        .4165
  4       3.585     1.098   -.1537    .2747     1.1508      .8981       .1019        .1019        .7149
  5       3.837     1.175   -.2100    .2983     1.2961      .8918       .1083        .1083       1.0000


                  ABSOLUTE VELOCITY (FPS)                           RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL    TANGENTIAL   OVERALL      AXIAL      RADIAL    TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT    COMPONENT   COMPONENT    VELOCITY    COMPONENT   COMPONENT   COMPONENT   VELOCITY     VELOCITY

  1     331.43      -13.29     -210.08      392.63      331.43      -13.29     -797.60      863.82       587.52
  2     304.47        2.89      -40.56      307.17      304.47        2.89     -699.40      762.81       658.84
  3     333.18        7.62      -27.51      334.41      333.18        7.62     -739.83      811.43       712.31
  4     383.43       33.30      -19.55      385.37      383.43       33.30     -801.76      809.36       782.21
  5     431.85       51.24      -25.64      435.64      431.85       51.24     -862.75      966.15       837.11


          MACH NUMBER            FLOW ANGLE           TEMPERATURE            PRESSURE              PRESSURE
                                   (DEG)               (DEG. R)               (PSI)                  RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE    ABSOLUTE  RELATIVE     TOTAL    STATIC       TOTAL    STATIC      TOT/TOT    TOT/STA

  1        .37       .80       -32.37    -67.44     493.64    480.81      14.498    13.222      2.2307     2.4460
  2        .28       .70        -7.59    -66.48     507.91    500.06      16.300    15.435      1.9841     2.0953
  3        .31       .74        -4.72    -65.76     508.47    499.16      16.353    15.330      1.9776     2.1096
  4        .35       .81        -2.92    -64.45     509.06    496.70      16.290    14.948      1.9852     2.1635
  5        .40       .89        -3.40    -63.41     508.54    492.75      16.059    14.381      2.0138     2.2488


STREAM  EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE    TEMPERATURE    INLET       PRESSURE
                      PRESSURE       RATIO
         (DEG. R)      (PSI
  1      542.90       21.238         1.6
  2      548.48       22.107         1.4
  3      553.95       22.972         1.5
  4      562.52       24.364         1.6
  5      570.42       25.684         1.8
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                             SET     PAGE       RPM       TOTAL/STATIC      INLET TOTAL   INLET TOTAL
                            NUMBER  NUMBER               PRESSURE RATIO     PRESSURE      TEMPERATURE
                                                                             (PSI)         (DEG. R)

                              1       3      25000.0          2.200          32.340         603.60


                                        .OVERALL TURBINE CHARACTERISTICS


 STREAM       PRESSURE RATIO          EFFICIENCY             HEAD         BLADE/JET     THEORETICAL
  LINE      TOT/STA   TOT/TOT     TOT/STA     TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1        2.4460    2.2307       .8079       .8893        4.4985         .4715          .3609
   2        2.0953    1.9841       .8322       .8917        3.2191         .5574          .3275
   3        2.1096    1.9776       .8206       .8904        2.8666         .5906          .3989
   4        2.1635    1.9852       .7916       .8803        2.5607         .6249          .4096
  .5        2.2488    2.0138       .7620       .8680        2.3944         .6462          .5652


                                                MASS AVERAGED QUANTITIES


                                                HORSE POWER =     137.41   (HP)
                                                MOMENT      =      28.87   (FT-LB)
                                                FLOW RATE   =       4.18   (LB/SEC)


                                         REFERRED  RPM         =  23168.50
                                         REFERRED HORSE POWER =      57.88   (HP)
                                         REFERRED MOMENT      =      13.12   (FT-LB)
                                         REFERRED FLOW RATE   =       2.05   (LB/SEC)


                                      TOTAL/STATIC EFFICIENCY =      .8073
                                      TOTAL/TOTAL   EFFICIENCY=      .8854
                                   TOTAL/STATIC PRESSURE RATIO =    2.1720
                                   TOTAL/TOTAL  PRESSURE RATIO =    2.0173


                                 HEAD COEFFICIENT              =    3.0232
                                 BLADE/JET SPEED RATIO         =     .5751
                                 THEORETICAL DEGREE OF REACTION=     .4198
                                 MACH NUMBER AT STATION 0      =     .2047
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              SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
            NUMBER   NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
              1        1      30000.0        2.200          32.340          603.60

                                        STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL    BLADE       Y=VA./VAM     BLADE        LOSS          ZETA*         FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                 (IN)     (IN)
   1       2.764        .865   0.0000     .2126       1.1037        .9179        .0021         .0021          0.0000
   2       3.003        .940   0.0000     .2347       1.0477        .9136        .0864         .0864           .2545
   3       3.195       1.000    .0290     .2526       1.0000        .9102        .0890         .0098           .4743
   4       3.432       1.074   0.0000     .2745        .9396        .9081        .0919         .0919           .7577
   5       3.627       1.135   0.0000     .2926        .8898        .9065        .0935         .0935          1.0000

                    ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY      COMPONENT   COMPONENT   COMPONENT     VELOCITY      VELOCITY

   1    403.41       -16.18       891.15        978.34         403.41     -16.18       167.53       437.11        723.62
   2    382.94         3.64       836.55        920.04         382.94       3.64        50.34       306.25        786.21
   3    370.16         8.36       791.33        871.70         370.16       8.36       -45.25       373.01        836.58
   4    343.44        29.83       737.61        814.19         343.44      29.83      -160.80       300.39        898.41
   5    325.22        38.58       693.87        767.27         325.22      38.58      -255.68       415.48        949.55

               MACH NUMBER               FLOW ANGLE              TEMPERATURE               PRESSURE               PRESSURE
                                           (DEG)                  (DEG. R)                   (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE         TOTAL      STATIC        TOTAL      STATIC        TOT/TOT     TOT/STA

   1         .87        .39           65.65      22.55          603.60     523.95        30.828     18.787        1.0490      1.7214
   2         .81        .34           65.41       7.49          603.60     533.16        30.948     20.046        1.0450      1.6133
   3         .76        .33           65.21      -6.97          603.60     540.37        31.052     21.081        1.0415      1.5341
   4         .71        .33           65.04     -25.09          603.60     548.44        31.203     22.311        1.0364      1.4475
   5         .66        .36           64.89     -38.18          603.60     554.61        31.320     23.290        1.0326      1.3006
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                              SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                            NUMBER   NUMBER               PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                                              (PSI)        (DEG. R)

                               1        2     30000.0         2.200          32.340        603.60


                                                         ROTOR EXIT SOLUTION


STREAM     RADIAL        X=R/RM    RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS          ZETA*          FLOW RATE
 LINE     POSITION                 SHIFT     OPENING               EFFICIENCY    COEFFICIENT    CONTINUITY      FRACTION

   1        2.693          .825     .0710      .1912      1.0024       .9152          .0849          .0849          0.0000
   2        3.020          .925    -.0168      .2218       .8883       .8969          .1032          .1032           .2166
   3        3.265         1.000    -.0405      .2447      1.0000       .8831          .1169          .1169           .4058
   4        3.585         1.098    -.1537      .2747      1.1837       .8931          .1069          .1069           .7051
   5        3.837         1.175    -.2100      .2983      1.3551       .9010          .0991          .0991          1.0000


                    ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL    TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY       COMPONENT    COMPONENT   COMPONENT     VELOCITY      VELOCITY

   1     331.81        -13.31       -93.49       344.99          331.81      -13.31      -798.52       864.82        705.03
   2     294.05          2.79       115.13       315.80          294.05        2.79      -675.48       736.72        790.61
   3     331.02          7.57       119.75       352.10          331.02        7.57      -735.03       806.16        854.78
   4     391.84         34.03       119.31       411.01          391.84       34.03      -819.34       908.65        938.65
   5     448.58         53.22       108.37       464.54          448.50       53.22      -896.16      1003.57       1004.53


             MACH NUMBER              FLOW ANGLE                 TEMPERATURE              PRESSURE                  PRESSURE
                                        (DEG)                     (DEG. R)                 (PSI)                     RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE         TOTAL     STATIC          TOTAL     STATIC         TOT/TOT     TOT/STA

   1          .32        .81       -15.74     -67.44         485.31     475.41         13.767     12.808         2.3491      2.5249
   2          .29        .67        21.38     -66.48         509.29     500.99         16.465     15.545         1.9642      2.0805
   3          .32        .74        19.89     -65.76         510.46     500.43         16.422     15.320         1.9693      2.1109
   4          .38        .83        16.94     -64.45         511.95     497.90         16.541     15.005         1.9552      2.1553
   5          .43        .92        13.58     -63.41         512.07     494.11         16.490     14.553         1.9612      2.2222


STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE      TEMPERATURE    INLET         PRESSURE
                         PRESSURE       RATIO
           (DEG. R)      (PSI
   1        537.64        20.561         1.6
   2        546.16        21.808         1.4
   3        554.51        23.075         1.5
   4        566.63        25.011         1.7
   5        577.92        26.899         1.8
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                                 SET      PAGE      RPM      TOTAL/STATIC    INLET TOTAL    INLET TOTAL
                               NUMBER   NUMBER             PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                                               (PSI)        (DEG. R)

                                  1        3     30000.0        2.200         32.340         603.60


                                              OVERALL TURBINE CHARACTERISTICS


STREAM       PRESSURE RATIO              EFFICIENCY               HEAD          BLADE/JET     THEORETICAL
 LINE     TOT/STA     TOT/TOT       TOT/STA        TOT/TOT     COEFFICIENT    SPEED RATIO DEGREE OF REACTION

  1        2.5249      2.3491        .8429          .9051        3.2209          .5572           .3817
  2        2.0805      1.9642        .8273          .8907        2.2162          .6717           .3237
  3        2.1109      1.9693        .8028          .8766        1.9922          .7085           .4012
  4        2.1553      1.9552        .7707          .8710        1.7704          .7516           .4892
  5        2.2222      1.9612        .7434          .8663        1.6410          .7806           .5611


                                                 MASS AVERAGED QUANTITIES


                                             HORSE POWER =      136.86    (HP)
                                             MOMENT      =       23.96    (FT-LB)
                                             FLOW RATE   =        4.22    (LB/SEC)

                                  REFERRED  RPM          =   27802.20
                                  REFERRED HORSE POWER   =       57.65    (HP)
                                  REFERRED MOMENT        =       10.89    (FT-LB)
                                  REFERRED FLOW RATE     =        2.07    (LB/SEC)

                              TOTAL/STATIC EFFICIENCY =          .7985
                              TOTAL/TOTAL   EFFICIENCY=          .8810
                         TOTAL/STATIC PRESSURE RATIO =          2.1801
                         TOTAL/TOTAL  PRESSURE RATIO =          2.0110

                       HEAD COEFFICIENT                 =       2.1024
                       BLADE/JET SPEED RATIO            =        .6897
                       THEORETICAL DEGREE OF REACTION=           .4214
                       MACH NUMBER AT STATION 0         =        .2068
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                                   SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                                  NUMBER   NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                    1        1      10000.0         2.400           35.280         615.30


                                                                    STATOR EXIT SOLUTION


 STREAM     RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS          ZETA*         FLOW RATE
  LINE     POSITION               SHIFT     OPENING                 EFFICIENCY   COEFFICIENT    CONTINUITY      FRACTION

             (IN)                  (IN)      (IN)
   1        2.764        .865    0.0000      .2126      1.1059         .9195         .0805          .0805          0.0000
   2        3.003        .940    0.0000      .2347      1.0486         .9125         .0875          .0875           .2499
   3        3.195       1.000     .0290      .2526      1.0000         .9068         .0932          .0932           .4680
   4        3.432       1.074    0.0000      .2745       .9387         .9015         .0985          .0985           .7531
   5        3.627       1.135    0.0000      .2926       .8803         .8972         .1028          .1028          1.0000


                     ABSOLUTE VELOCITY (FPS)                                   RELATIVE VELOCITY (FPS)

 STREAM     AXIAL         RADIAL      TANGENTIAL     OVERALL          AXIAL       RADIAL     TANGENTIAL     OVERALL        WHEEL
  LINE  COMPONENT      COMPONENT      COMPONENT     VELOCITY       COMPONENT   COMPONENT     COMPONENT     VELOCITY       VELOCITY

   1      473.88         -19.01        1046.83       1149.25         473.88      -19.01        805.62        934.85        241.21
   2      449.34           4.27         981.58       1079.55         449.34        4.27        719.52        848.31        262.07
   3      428.49           9.80         927.73       1021.95         428.49        9.80        648.87        777.65        278.86
   4      402.24          34.94         863.90        953.59         402.24       34.94        564.43        693.97        299.47
   5      380.61          45.16         812.06        897.97         380.61       45.16        495.54        626.47        316.52


                  MACH NUMBER               FLOW ANGLE             TEMPERATURE            PRESSURE                PRESSURE
                                              (DEG)                 (DEG. R)               (PSI)                   RATIO
 STREAM
  LINE      ABSOLUTE   RELATIVE        ABSOLUTE   RELATIVE        TOTAL     STATIC       TOTAL     STATIC        TOT/TOT    TOT/STA

   1          1.04        .85            65.65      59.54         615.30    505.40       32.985    16.566         1.0696     2.1296
   2           .97        .76            65.41      58.02         615.30    518.32       33.113    18.167         1.0654     1.9419
   3           .91        .69            65.21      56.56         615.30    528.39       33.236    19.506         1.0615     1.8087
   4           .84        .61            65.04      54.53         615.30    539.63       33.425    21.116         1.0555     1.6708
   5           .78        .55            64.89      52.48         615.30    548.20       33.578    22.415         1.0507     1.5739
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          SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
         NUMBER  NUMBER              PRESSURE RATIO  PRESSURE      TEMPERATURE
                                                      (PSI)         (DEG. R)

           1       2     10000.0        2.400        35.280         615.30


                                          ROTOR EXIT SOLUTION


STREAM   RADIAL     X=R/RM   RADIAL    BLADE      Y=VA /VAM    BLADE       LOSS         ZETA*        FLOW RATE
 LINE    POSITION            SHIFT    OPENING                EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

   1      2.693      .825    .0710     .1912      .9754       .8379        .1621        .1621        0.0000
   2      3.028      .925   -.0168     .2218      .9888       .8364        .1637        .1637         .2359
   3      3.265     1.000   -.0405     .2447     1.0000       .8352        .1649        .1649         .4371
   4      3.585     1.098   -.1537     .2747     1.0449       .8402        .1599        .1599         .7311
  .5     .3.837     1.175   -.2100     .2983     1.1009       .8441        .1559        .1559        1.0000

                  ABSOLUTE VELOCITY (FPS)                              RELATIVE VELOCITY (FPS)

STREAM   AXIAL       RADIAL     TANGENTIAL   OVERALL        AXIAL      RADIAL     TANGENTIAL   OVERALL        WHEEL
 LINE  COMPONENT   COMPONENT    COMPONENT    VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY      VELOCITY

   1    376.07      -15.09      -670.01      768.48       376.07      -15.09      -905.01      980.16        235.01
   2    381.24        3.62      -612.23      721.24       381.24        3.62      -875.77      955.16        263.54
   3    385.57        8.82      -571.23      689.23       385.57        8.82      -856.15      939.01        284.93
   4    402.88       34.99      -529.56      666.31       402.88       34.99      -842.44      934.47        312.88
   5    424.47       50.36      -513.15      667.86       424.47       50.36      -840.00      949.63        334.84

           MACH NUMBER              FLOW ANGLE             TEMPERATURE             PRESSURE              PRESSURE
                                      (DEG)                 (DEG. R)                (PSI)                 RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

   1        .70        .90        -60.70     -67.44       547.07    497.93       19.575    14.081       1.8023     2.5054
   2        .66        .87        -58.09     -66.48       545.64    502.35       19.576    14.658       1.8022     2.4068
   3        .63        .85        -55.99     -65.76       545.16    505.63       19.654    15.102       1.7950     2.3361
   4        .60        .85        -52.74     -64.45       544.67    507.73       19.805    15.488       1.7814     2.2779
   5        .61        .86        -50.41     -63.41       543.93    506.81       19.792    15.455       1.7825     2.2828


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
   1      577.87       26.481        1.9
   2      578.27       26.647        1.8
   3      579.00       26.865        1.8
   4      580.39       27.245        1.8
   5      581.85       27.612        1.8
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                         SET     PAGE      RPM     TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER            PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                     (PSI)        (DEG. R)

                          1       3     10000.0        2.400        35.280        615.30


                                     OVERALL TURBINE CHARACTERISTICS


 STREAM      PRESSURE RATIO            EFFICIENCY             HEAD        BLADE/JET    THEORETICAL
  LINE     TOT/STA    TOT/TOT      TOT/STA      TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1       2.5054     1.8023       .4804        .7159      29.3338         .1846          .1584
   2       2.4068     1.8022       .5102        .7310      23.8934         .2046          .2217
   3       2.3361     1.7950       .5296        .7406      20.4693         .2210          .2764
   4       2.2779     1.7814       .5477        .7540      17.2807         .2406          .3492
   5       2.2828     1.7825       .5522        .7620      15.5053         .2540          .4214


                                          MASS AVERAGED QUANTITIES


                                     HORSE POWER  =     109.48    (HP)
                                     MOMENT       =      57.50    (FT-LB)
                                     FLOW RATE    =       4.60    (LB/SEC)


                                REFERRED  RPM         =   9178.87
                                REFERRED HORSE POWER  =     41.87    (HP)
                                REFERRED MOMENT       =     23.96    (FT-LB)
                                REFERRED FLOW RATE    =      2.09    (LB/SEC)


                          TOTAL/STATIC EFFICIENCY  =      .5259
                           TOTAL/TOTAL  EFFICIENCY=       .7413
                      TOTAL/STATIC PRESSURE RATIO  =     2.3537
                      TOTAL/TOTAL  PRESSURE RATIO  =     1.7928


                   HEAD COEFFICIENT                 =   21.0157
                   BLADE/JET SPEED RATIO            =     .2181
                   THEORETICAL DEGREE OF REACTION=        .2843
                   MACH NUMBER AT STATION 0         =     .2084
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    SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
  NUMBER   NUMBER             PRESSURE RATIO    PRESSURE      TEMPERATURE
     1        1     15000.0        2.400          35.280         615.30


                                          STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS         ZETA*       FLOW RATE
 LINE    POSITION               SHIFT    OPENING                 EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

           (IN)                  (IN)     (IN)
   1       2.764        .865    0.0000    .2126       1.1043        .9122        .0878        .0878        0.0000
   2       3.003        .940    0.0000    .2347       1.0477        .9056        .0944        .0944         .2515
   3       3.195       1.000     .0290    .2526       1.0000        .9002        .0998        .0998         .4703
   4       3.432       1.074    0.0000    .2745        .9400        .9000        .1000        .1000         .7546
   5       3.627       1.135    0.0000    .2926        .8923        .8998        .1002        .1002        1.0000


                 ABSOLUTE VELOCITY (FPS)                             RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL      RADIAL    TANGENTIAL    OVERALL        WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT     VELOCITY      COMPONENT  COMPONENT   COMPONENT     VELOCITY      VELOCITY

   1     439.59       -17.63       971.07      1066.08         439.59     -17.63      609.26       751.50        361.81
   2     417.04         3.96       911.03      1001.96         417.04       3.96      517.93       664.97        393.10
   3     398.05         9.11       861.82       949.35         398.05       9.11      443.53       596.03        418.29
   4     374.50        32.53       804.34       887.84         374.50      32.53      355.13       517.14        449.20
   5     355.18        42.14       757.81       837.98         355.18      42.14      203.03       456.11        474.77


             MACH NUMBER                 FLOW ANGLE             TEMPERATURE             PRESSURE              PRESSURE
                                            (DEG)                 (DEG. R)                (PSI)                 RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE       ABSOLUTE  RELATIVE         TOTAL     STATIC        TOTAL     STATIC       TOT/TOT    TOT/STA

   1          .95        .67           65.65     54.19          615.30    520.73        33.169    18.496        1.0636     1.9075
   2          .89        .59           65.41     51.16          615.30    531.76        33.299    19.982        1.0595     1.7656
   3          .83        .52           65.21     48.10          615.30    540.30        33.417    21.203        1.0557     1.6639
   4          .77        .45           65.04     43.48          615.30    549.71        33.670    22.693        1.0478     1.5547
   5 .        .72        .39           64.89     38.55          615.30    556.87        33.858    23.877        1.0420     1.4775
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                         SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                                        (PSI)        (DEG. R)

                          1        2     15000.0         2.400          35.280        615.30

                                                    ROTOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM    RADIAL     BLADE     Y=VA /VAM    BLADE        LOSS        ZETA*       FLOW RATE
 LINE    POSITION               SHIFT     OPENING               EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

   1       2.693        .825     .0710     .1912       .9810      .8603        .1397       .1397       0.0000
   2       3.020        .925   -.0168     .2218       .9666      .8647        .1354       .1354        .2320
   3       3.265       1.000   -.0405     .2447      1.0000      .8679        .1321       .1321        .4312
   4       3.585       1.098   -.1537     .2747      1.0753      .8761        .1239       .1239        .7262
   5       3.837       1.175   -.2100     .2983      1.1567      .8825        .1175       .1175       1.0000

                ABSOLUTE VELOCITY (FPS)                                      RELATIVE VELOCITY (FPS)

STREAM     AXIAL        RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE  COMPONENT      COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT     VELOCITY      VELOCITY

   1     361.69        -14.51       -517.91       631.88       361.69      -14.51      -870.43       942.70        352.51
   2     356.38          3.39       -423.34       553.39       356.38        3.39      -818.65       892.86        395.31
   3     368.69          8.44       -391.28       537.69       368.69        8.44      -818.67       897.28        427.39
   4     396.46         34.43       -359.70       536.42       396.46       34.43      -829.02       919.59        469.33
   5     426.46         50.60       -349.72       553.83       426.46       50.60      -851.98       954.10        502.26

            MACH NUMBER               FLOW ANGLE             TEMPERATURE             PRESSURE               PRESSURE
                                        (DEG)                 (DEG. R)                 (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE      TOTAL    STATIC        TOTAL     STATIC       TOT/TOT     TOT/STA

   1         .58        .87         -55.07     -67.44      526.44    493.22       17.627    14.031        2.0014      2.5144
   2         .50        .81         -49.91     -66.48      527.85    502.37       18.099    15.221        1.9493      2.3179
   3         .49        .82         -46.71     -65.76      527.47    503.42       18.143    15.409        1.9445      2.2896
   4         .49        .84         -42.22     -64.45      527.07    503.13       18.265    15.522        1.9316      2.2729
   5         .50        .87         -39.36     -63.41      526.19    500.67       18.236    15.323        1.9347      2.3024

STREAM    EQUIVALENT    EQUIVALENT    EQUIV/STATIC
 LINE     TEMPERATURE     INLET        PRESSURE
                         PRESSURE        RATIO
           (DEG. R)       (PSI
   1       567.17         24.942          1.8
   2       568.70         25.277          1.7
   3       570.50         25.649          1.7
   4       573.50         26.321          1.7
   5       576.41         26.942          1.8
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   SET       PAGE        RPM        TOTAL/STATIC      INLET TOTAL     INLET TOTAL
  NUMBER    NUMBER                PRESSURE RATIO     PRESSURE      TEMPERATURE
                                                       (PSI)         (DEG. R)

    1          3      15000.0          2.400          35.280          615.30


                         OVERALL TURBINE CHARACTERISTICS

STREAM       PRESSURE RATIO            EFFICIENCY              HEAD       BLADE/JET      THEORETICAL
 LINE     TOT/STA    TOT/TOT      TOT/STA        TOT/TOT   COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.5144     2.0014       .6236          .8031      13.0814        .2765          .2725
  2       2.3179     1.9493       .6657          .8186      10.2166        .3129          .2978
  3       2.2896     1.9445       .6773          .8249       8.9067        .3351          .3576
  4       2.2729     1.9316       .6857          .8363       7.6624        .3613          .4335
  5       2.3024     1.9347       .6831          .8428       6.9546        .3792          .5022

                               MASS AVERAGED QUANTITIES

                             HORSE POWER =     135.97    (HP)
                             MOMENT      =      47.61    (FT-LB)
                             FLOW RATE   =       4.54    (LB/SEC)

                  REFERRED  RPM          =  13760.30
                  REFERRED HORSE POWER   =      52.00    (HP)
                  REFERRED MOMENT        =      19.84    (FT-LB)
                  REFERRED FLOW RATE     =       2.06    (LB/SEC)

              TOTAL/STATIC EFFICIENCY =        .6705
              TOTAL/TOTAL  EFFICIENCY=         .8257
           TOTAL/STATIC PRESSURE RATIO =      2.3222
           TOTAL/TOTAL  PRESSURE RATIO =      1.9484

         HEAD COEFFICIENT               =      9.2009
         BLADE/JET SPEED RATIO          =       .3297
         THEORETICAL DEGREE OF REACTION=        .3691
         MACH NUMBER AT STATION 0       =       .2057
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                     SET     PAGE          RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                    NUMBER  NUMBER                 PRESSURE RATIO    PRESSURE      TEMPERATURE
                      1       1      20000.0           2.400          35.200          615.30


                                                      STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE        LOSS          ZETA*         FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

           (IN)                 (IN)      (IN)
  1        2.764        .865   0.0000     .2126       1.1017        .9133        .0867         .0867          0.0000
  2        3.003        .940   0.0000     .2347       1.0470        .9104        .0096         .0896           .2520
  3        3.195       1.000    .0290     .2526       1.0000        .9000        .0920         .0920           .4713
  4        3.432       1.074   0.0000     .2745        .9401        .9061        .0939         .0939           .7556
  5        3.627       1.135   0.0000     .2926        .8905        .9045        .0955         .0955          1.0000


                       ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM     AXIAL       RADIAL     TANGENTIAL   OVERALL          AXIAL      RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT    VELOCITY       COMPONENT  COMPONENT    COMPONENT     VELOCITY        VELOCITY

  1      429.69       -17.24       949.20      1042.07          429.69     -17.24       466.79       634.69          482.41
  2      408.34         3.88       892.02       981.05          408.34       3.88       367.88       549.63          524.14
  3      390.02         8.92       844.44       930.20          390.02       8.92       286.72       484.16          557.72
  4      366.68        31.85       787.54       869.30          366.68      31.85       188.60       413.57          598.94
  5      347.33        41.21       741.05       819.45          347.33      41.21       108.02       366.07          633.03


                MACH NUMBER               FLOW ANGLE             TEMPERATURE               PRESSURE                PRESSURE
                                            (DEG)                  (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE      ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE         TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

  1           .93        .57          65.65      47.37          615.30    524.94        33.303    19.101        1.0594      1.8476
  2           .87        .48          65.41      42.02          615.30    535.21        33.494    20.559        1.0533      1.7160
  3           .81        .42          65.21      36.32          615.30    543.30        33.649    21.767        1.0405      1.6208
  4           .75        .36          65.04      27.22          615.30    552.42        33.845    23.207        1.0424      1.5202
  5           .71        .32          64.89      17.28          615.30    559.42        33.996    24.362        1.0378      1.4482
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            SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
           NUMBER  NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                          (PSI)        (DEG. R)

             1       2     20000.0          2.400         35.200        615.30


                                       ROTOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE      LOSS       ZETA*       FLOW RATE
 LINE    POSITION              SHIFT    OPENING                EFFICIENCY COEFFICIENT CONTINUITY  FRACTION

   1       2.693       .825    .0710    .1912      .9855       .8800       .1112      .1112       0.0000
   2       3.020       .925   -.0168    .2218      .9479       .8929       .1071      .1071        .2279
   3       3.265      1.000   -.0405    .2447     1.0000       .8960       .1040      .1040        .4256
   4       3.585      1.098   -.1537    .2747     1.1024       .9031       .0970      .0970        .7221
   5       3.837      1.175   -.2100    .2983     1.2069       .9086       .0914      .0914       1.0000


                  ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL   OVERALL       WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

   1     371.69      -14.91      -424.45       564.39        371.69     -14.91      -894.47      960.74       470.02
   2     357.52        3.40      -294.20       463.02        357.52       3.40      -821.28      895.73       527.07
   3     377.17        8.63      -267.65       462.57        377.17       8.63      -837.50      918.55       569.85
   4     415.78       36.11      -243.64       403.26        415.78      36.11      -869.41      964.39       625.77
   5     455.20       54.01      -239.71       517.29        455.20      54.01      -909.39     1018.39       669.68


           MACH NUMBER            FLOW ANGLE           TEMPERATURE              PRESSURE               PRESSURE
                                    (DEG)               (DEG. R)                 (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE     TOTAL     STATIC       TOTAL     STATIC      TOT/TOT    TOT/STA

   1        .53       .90        -48.80    -67.44      505.89    479.39      15.616    12.935      2.2542     2.7274
   2        .43       .82        -39.45    -66.48      511.68    493.84      16.589    14.651      2.1268     2.4080
   3        .42       .84        -35.36    -65.76      511.54    493.73      16.632    14.692      2.1212     2.4013
   4        .44       .89        -30.37    -64.45      511.43    491.99      16.693    14.576      2.1135     2.4204
   5        .48       .94        -27.77    -63.41      510.51    488.25      16.610    14.209      2.1241     2.4829


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE  INLET        PRESSURE
                      PRESSURE      RATIO
          (DEG. R)    (PSI
  1       557.48       23.576        1.8
  2       560.61       24.180        1.7
  3       563.94       24.802        1.7
  4       569.39       25.799        1.8
  5       574.55       26.746        1.9
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                      SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                    NUMBER   NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                                                   (PSI)        (DEG. R)

                       1        3    20000.0        2.400         35.280        615.30

                           .OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO            EFFICIENCY           HEAD         BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT      TOT/STA      TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

  1       2.7274     2.2592        .7134        .8560      7.9191        .3554           .3548
  2       2.4060     2.1268        .7584        .8683      5.9763        .4091           .3561
  3       2.4013     2.1212        .7616        .8723      5.2634        .4359           .4179
  4       2.4204     2.1135        .7564        .8770      4.6002        .4662           .4946
  5       2.4829     2.1241        .7443        .8795      4.2221        .4867           .5612

                                      MASS AVERAGED QUANTITIES

                                      HORSE POWER =      161.10     (HP)
                                      MOMENT      =       42.31     (FT-LB)
                                      FLOW RATE   =        4.54     (LB/SEC)

                             REFERRED  RPM         =  18357.73
                             REFERRED HORSE POWER =       61.61     (HP)
                             REFERRED MOMENT      =       17.63     (FT-LB)
                             REFERRED FLOW RATE   =        2.06     (LB/SEC)

                          TOTAL/STATIC EFFICIENCY =        .7513
                           TOTAL/TOTAL  EFFICIENCY=        .8713
                      TOTAL/STATIC PRESSURE RATIO =       2.4587
                      TOTAL/TOTAL  PRESSURE RATIO =       2.1303

                    HEAD COEFFICIENT               =       5.4776
                    BLADE/JET SPEED RATIO          =        .4273
                    THEORETICAL DEGREE OF REACTION=         .4317
                    MACH NUMBER AT STATION 0       =        .2055
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                    SET     PAGE       RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                  NUMBER   NUMBER               PRESSURE RATIO     PRESSURE      TEMPERATURE
                    1        1      30000.0         2.400           35.280          615.30


                                                        STATOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS         ZETA*       FLOW RATE
 LINE    POSITION               SHIFT    OPENING                  EFFICIENCY   COEFFICIENT  CONTINUITY    FRACTION

           (IN)                  (IN)      (IN)
  1        2.764        .865    0.0000     .2126       1.1040        .9194         .0806        .0806        0.0000
  2        3.003        .940    0.0000     .2347       1.0479        .9149         .0851        .0851         .2530
  3        3.195       1.000     .0290     .2526       1.0000        .9113         .0887        .0887         .4734
  4        3.432       1.074    0.0000     .2745        .9395        .9090         .0910        .0910         .7571
  5        3.627       1.135    0.0000     .2926        .8895        .9071         .0929        .0929        1.0000


                 ABSOLUTE VELOCITY (FPS)                                     RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT     VELOCITY      COMPONENT    COMPONENT    COMPONENT     VELOCITY       VELOCITY

  1     416.68       -16.71       920.47       1010.53        416.68       -16.71       196.86       461.15         723.62
  2     395.49         3.76       863.95        950.17        395.49         3.76        77.74       403.07         786.21
  3     377.42         8.64       817.15        900.14        377.42         8.64       -19.43       378.02         836.58
  4     354.58        30.80       761.55        840.62        354.58        30.80      -136.86       381.32         898.41
  5     335.72        39.83       716.29        792.06        335.72        39.83      -233.26       410.74         949.55


             MACH NUMBER               FLOW ANGLE              TEMPERATURE             PRESSURE               PRESSURE
                                         (DEG)                  (DEG. R)                (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE       TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1          .90        .41          65.65      25.29        615.30    530.33       33.575    19.958       1.0508     1.7677
  2          .83        .35          65.41      11.12        615.30    540.17       33.708    21.370       1.0466     1.6509
  3          .78        .33          65.21      -2.95        615.30    547.08       33.822    22.532       1.0431     1.5650
  4          .73        .33          65.04     -21.11        615.30    556.50       33.991    23.916       1.0379     1.4752
  5          .68        .35          64.89     -34.79        615.30    563.10       34.122    25.019       1.0339     1.4101
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        SET    PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
      NUMBER  NUMBER            PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                   (PSI)         (DEG. R)

         1       2    30000.0        2.400         35.280        615.30


                                        ROTOR EXIT SOLUTION


STREAM   RADIAL     X=R/RM   RADIAL    BLADE     Y=VA /VAM     BLADE        LOSS        ZETA*      FLOW RATE
 LINE   POSITION             SHIFT    OPENING               EFFICIENCY   COEFFICIENT  CONTINUITY   FRACTION

   1      2.693      .825    .0710     .1912     1.0001       .9163        .0837        .0837       0.0000
   2      3.020      .925   -.0168     .2218      .8969       .8989        .1012        .1012        .2180
   3      3.265     1.000   -.0405     .2447     1.0000       .8858        .1142        .1142        .4086
   4      3.585     1.098   -.1537     .2747     1.1731       .8982        .1018        .1018        .7074
   5      3.837     1.175   -.2100     .2983     1.3365       .9080        .0920        .0920       1.0000


                  ABSOLUTE VELOCITY (FPS)                          RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT    COMPONENT    COMPONENT    VELOCITY    COMPONENT   COMPONENT   COMPONENT    VELOCITY     VELOCITY

   1    351.32      -14.09      -140.43      378.60       351.32      -14.09     -845.45      915.65       705.03
   2    315.07        2.99        66.87      322.10       315.07        2.99     -723.75      789.36       790.61
   3    351.28        8.04        74.77      359.24       351.28        8.04     -780.01      855.50       854.78
   4    412.09       35.79        76.97      420.74       412.09       35.79     -861.69      955.82       938.65
   5    469.47       55.70        66.63      477.43       469.47       55.70     -937.90     1050.31      1004.53


          MACH NUMBER            FLOW ANGLE            TEMPERATURE           PRESSURE             PRESSURE
                                   (DEG)                 (DEG. R)              (PSI)                RATIO
STREAM
 LINE   ABSOLUTE  RELATIVE   ABSOLUTE  RELATIVE      TOTAL    STATIC       TOTAL    STATIC     TOT/TOT    TOT/STA

   1       .35      .86       -21.79    -67.44      487.97    476.05      14.227    13.047     2.4798     2.7041
   2       .29      .72        11.98    -66.48      511.06    502.42      16.897    15.919     2.0879     2.2162
   3       .33      .78        12.02    -65.76      512.17    501.43      16.840    15.636     2.0950     2.2563
   4       .38      .87        10.58    -64.45      513.46    498.73      16.976    15.332     2.0782     2.3011
   5       .44      .96         8.08    -63.41      513.25    494.28      16.923    14.833     2.0847     2.3784


STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
   1      545.81        22.073        1.7
   2      554.27        23.386        1.5
   3      562.33        24.681        1.6
   4      574.75        26.776        1.7
   5      586.07        28.778        1.9
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          SET      PAGE       RPM        TOTAL/STATIC      INLET TOTAL    INLET TOTAL
         NUMBER   NUMBER                PRESSURE RATIO     PRESSURE      TEMPERATURE
                                                             (PSI)         (DEG. R)

           1         3     30000.0           2.400           35.280         615.30

                              . OVERALL TURBINE CHARACTERISTICS

STREAM      PRESSURE RATIO             EFFICIENCY              HEAD         BLADE/JET      THEORETICAL
 LINE     TOT/STA     TOT/TOT     TOT/STA       TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.7041      2.4798      .8365         .9055        3.4936         .5350            .3928
  2       2.2162      2.0879      .8331         .8932        2.4320         .6411            .3438
  3       2.2563      2.0950      .8080         .8800        2.1916         .6755            .4203
  4       2.3011      2.0782      .7812         .8776        1.9410         .7178            .5030
 .5     . 2.3784      2.0847      .7564         .8761        1.7983         .7457            .5735

                                          MASS AVERAGED QUANTITIES
                                                     .

                                      HORSE POWER =     161.77    (HP)
                                      MOMENT      =      28.32    (FT-LB)
                                      FLOW RATE   =       4.52    (LB/SEC)

                                REFERRED  RPM         =  27536.60
                                REFERRED HORSE POWER =     61.97    (HP)
                                REFERRED MOMENT      =     11.80    (FT-LB)
                                REFERRED FLOW RATE   =      2.05    (LB/SEC)

                            TOTAL/STATIC EFFICIENCY =      .8047
                            TOTAL/TOTAL  EFFICIENCY=       .8854
                         TOTAL/STATIC PRESSURE RATIO =    2.3287
                         TOTAL/TOTAL  PRESSURE RATIO =    2.1350

                     HEAD COEFFICIENT                =    2.3029
                     BLADE/JET SPEED RATIO           =     .6590
                     THEORETICAL DEGREE OF REACTION=       .4378
                     MACH NUMBER AT STATION 0        =     .2045
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            SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL  INLET TOTAL
          NUMBER   NUMBER              PRESSURE RATIO    PRESSURE    TEMPERATURE
             1        1     20000.0         2.600          38.220        626.18

                                              STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM    RADIAL    BLADE      Y=VA /VAM      BLADE       LOSS          ZETA*          FLOW RATE
 LINE    POSITION                 SHIFT   OPENING                 EFFICIENCY  COEFFICIENT   CONTINUITY     FRACTION

           (IN)                   (IN)     (IN)
  1        2.764        .865     0.0000    .2126       1.1017        .9134       .0866          .0866          0.0000
  2        3.003        .940     0.0000    .2347       1.0469        .9105       .0895          .0895           .2518
  3        3.195       1.000      .0290    .2526       1.0000        .9082       .0918          .0918           .4710
  4        3.432       1.074     0.0000    .2745        .9401        .9062       .0938          .0938           .7554
  5        3.627       1.135     0.0000    .2926        .8905        .9046       .0954          .0954          1.0000

                       ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL         AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT    VELOCITY      COMPONENT   COMPONENT    COMPONENT    VELOCITY      VELOCITY

  1      436.14        -17.50       963.46      1057.73         436.14      -17.50       401.05       649.57        402.41
  2      414.48          3.94       905.45       995.81         414.48        3.94       301.31       563.21        524.14
  3      395.90          9.06       857.16       944.21         395.90        9.06       299.44       496.47        557.72
  4      372.19         32.33       799.38       882.37         372.19       32.33       200.44       423.97        598.94
  5      352.54         41.83       752.17       831.74         352.54       41.83       119.14       374.47        633.03

               MACH NUMBER              FLOW ANGLE              TEMPERATURE            PRESSURE               PRESSURE
                                          (DEG)                  (DEG. R)                (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE       ABSOLUTE   RELATIVE       TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1          .93        .57          65.65      47.81        626.18     533.08      36.051    20.524       1.0602     1.8622
  2          .87        .49          65.41      42.62        626.18     543.66      36.261    22.113       1.0540     1.7284
  3          .82        .43          65.21      37.10        626.18     551.99      36.433    23.432       1.0491     1.6311
  4          .76        .37          65.04      28.31        626.18     561.39      36.646    25.005       1.0429     1.5285
  5          .71        .32          64.89      18.67        626.18     568.61      36.811    26.266       1.0383     1.4551
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                      SET      PAGE        RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                     NUMBER   NUMBER               PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                                        (PSI)         (DEG. R)

                       1         2      20000.0         2.600           38.220         626.18

                                                    ROTOR EXIT SOLUTION

STREAM    RADIAL        X=R/RM   RADIAL     BLADE     Y=VA /VAM     BLADE        LOSS          ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING                 EFFICIENCY   COEFFICIENT    CONTINUITY    FRACTION

   1       2.693         .825    .0718     .1912       .9841       .8925         .1076         .1076        0.0000
   2       3.020         .925   -.0168     .2218       .9534       .8962         .1039         .1039         .2284
   3       3.265        1.000   -.0405     .2447      1.0000       .8790         .1011         .1011         .4268
   4       3.585        1.098   -.1537     .2747      1.0944       .9058         .0943         .0943         .7231
   5       3.837        1.175   -.2100     .2983      1.1922       .9111         .0889         .0889        1.0000

                   ABSOLUTE VELOCITY (FPS)                               RELATIVE VELOCITY (FPS)

STREAM    AXIAL        RADIAL     TANGENTIAL    OVERALL        AXIAL       RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT     COMPONENT     COMPONENT    VELOCITY     COMPONENT   COMPONENT    COMPONENT    VELOCITY      VELOCITY

   1     399.16       -16.01       -490.56      632.64        399.16      -16.01      -960.58      1040.34        470.02
   2     386.72         3.67       -361.27      529.23        386.72        3.67      -888.34       968.88        527.07
   3     405.61         9.28       -330.81      523.49        405.61        9.28      -900.66       987.82        569.85
   4     443.92        38.56       -302.49      538.56        443.92       38.56      -928.26      1029.67        625.77
   5     483.56        57.37       -296.36      570.04        483.56       57.37      -966.04      1081.83        669.68

           MACH NUMBER              FLOW ANGLE               TEMPERATURE               PRESSURE               PRESSURE
                                      (DEG)                   (DEG. R)                   (PSI)                   RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE       TOTAL     STATIC         TOTAL     STATIC        TOT/TOT     TOT/STA

   1        .59        .97        -50.87     -67.44        510.46    477.15        16.268    12.846         2.3494      2.9751
   2        .49        .89        -43.05     -66.48        515.51    492.20        17.203    14.631         2.2217      2.6122
   3        .48        .91        -39.20     -65.76        515.25    492.44        17.245    14.718         2.2163      2.5968
   4        .50        .95        -34.27     -64.45        515.00    490.86        17.306    14.630         2.2085      2.6125
   5        .53       1.00        -31.51     -63.41        513.91    486.87        17.205    14.240         2.2214      2.6840

STREAM   EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE     TEMPERATURE   INLET          PRESSURE
                       PRESSURE         RATIO
          (DEG. R)     (PSI
   1       567.21        25.502          2.0
   2       570.32        26.146          1.8
   3       573.64        26.810          1.8
   4       579.08        27.873          1.9
   5       584.26        28.883          2.0
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                         SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER              PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                                        (PSI)        (DEG. R)

                          1       3     20000.0         2.600          38.220         626.18


                                 .OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO           EFFICIENCY             HEAD         BLADE/JET      THEORETICAL
 LINE     TOT/STA   TOT/TOT     TOT/STA      TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

  1       2.9751    2.3494       .6905        .8535        8.6546         .3399            .3919
  2       2.6122    2.2217       .7367        .8667        6.5718         .3901            .3968
  3       2.5968    2.2163       .7424        .8711        5.7731         .4162            .4533
  4       2.6125    2.2085       .7400        .8765        5.0333         .4457            .5242
  5       2.6840    2.2214       .7295        .8793        4.6155         .4655            .5865


                                            MASS AVERAGED QUANTITIES


                                          HORSE POWER =     185.30    (HP)
                                          MOMENT      =      48.66    (FT-LB)
                                          FLOW RATE   =       4.89    (LB/SEC)

                                 REFERRED  RPM         =  18197.55
                                 REFERRED HORSE POWER =      64.84    (HP)
                                 REFERRED MOMENT      =      18.72    (FT-LB)
                                 REFERRED FLOW RATE   =       2.07    (LB/SEC)

                              TOTAL/STATIC EFFICIENCY =      .7323
                              TOTAL/TOTAL   EFFICIENCY=      .8702
                          TOTAL/STATIC PRESSURE RATIO =     2.6628
                          TOTAL/TOTAL  PRESSURE RATIO =     2.2330

                      HEAD COEFFICIENT                =     6.0033
                      BLADE/JET SPEED RATIO           =      .4081
                      THEORETICAL DEGREE OF REACTION=        .4659
                      MACH NUMBER AT STATION 0        =      .2061
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                                SET      PAGE        RPM      TOTAL/STATIC     INLET TOTAL    INLET TOTAL
                              NUMBER   NUMBER               PRESSURE RATIO   PRESSURE       TEMPERATURE
                                 1        1      30000.0        2.600          38.220          626.18

                                                       STATOR EXIT SOLUTION

STREAM   RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM      BLADE         LOSS         ZETA*        FLOW RATE
 LINE   POSITION                SHIFT    OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

          (IN)                  (IN)      (IN)
  1       2.764        .865    0.0000     .2126      1.1042        .9205         .0795        .0795        0.0000
  2       3.003        .940    0.0000     .2347      1.0400        .9159         .0841        .0841         .2532
  3       3.195       1.000     .0290     .2526      1.0000        .9123         .0877        .0877         .4727
  4       3.432       1.074    0.0000     .2745       .9393        .9098         .0902        .0902         .7566
  5       3.627       1.135    0.0000     .2926       .8892        .9077         .0923        .0923        1.0000

                  ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL         AXIAL      RADIAL     TANGENTIAL    OVERALL          WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT     VELOCITY      COMPONENT   COMPONENT   COMPONENT     VELOCITY        VELOCITY

  1     427.64       -17.15       944.68       1037.11         427.64     -17.15      221.06       481.71          723.62
  2     405.86         3.86       886.61        975.10         405.86       3.86      100.40       418.12          786.21
  3     387.29         8.86       838.53        923.69         387.29       8.86        1.94       387.40          836.58
  4     363.80        31.60       781.35        862.47         363.80      31.60     -117.06       383.47          898.41
  5     344.40        40.86       734.79        812.52         344.40      40.86     -214.76       407.92          949.55

              MACH NUMBER               FLOW ANGLE              TEMPERATURE              PRESSURE                PRESSURE
                                          (DEG)                   (DEG. R)                 (PSI)                   RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE        TOTAL     STATIC        TOTAL     STATIC        TOT/TOT     TOT/STA

  1          .91        .42          65.65      27.34        626.18     536.68       36.326     21.173        1.0521      1.8052
  2          .85        .36          65.41      13.90        626.18     547.06       36.474     22.733        1.0479      1.6813
  3          .80        .34          65.21        .29        626.18     555.18       36.601     24.020        1.0442      1.5912
  4          .74        .33          65.04     -17.84        626.18     564.28       36.784     25.554        1.0390      1.4957
  5          .69        .35          64.89     -31.95        626.18     571.24       36.927     26.778        1.0350      1.4273
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                                     SET     PAGE       RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
                                   NUMBER   NUMBER             PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                                   (PSI)        (DEG. R)

                                      1        2     30000.0       2.600          38.220        626.18


                                                                 ROTOR EXIT SOLUTION


 STREAM    RADIAL         X=R/RM   RADIAL     BLADE       Y=VA /VAM    BLADE        LOSS          ZETA*         FLOW RATE
  LINE    POSITION                 SHIFT     OPENING                 EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION

   1       2.693           .825     .0710     .1912        .9966       .9210        .0790         .0790        0.0000
   2       3.020           .925   -.0168      .2218        .9100       .9055        .0946         .0946         .2200
   3       3.265          1.000   -.0405      .2447       1.0000       .8938        .1063         .1063         .4133
   4       3.585          1.098   -.1537      .2747       1.1540       .9052        .0949         .0949         .7111
   5       3.837          1.175   -.2100      .2983       1.3010       .9141        .0859         .0859        1.0000


                          ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

 STREAM    AXIAL         RADIAL     TANGENTIAL     OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL         WHEEL
  LINE COMPONENT       COMPONENT    COMPONENT      VELOCITY       COMPONENT   COMPONENT    COMPONENT     VELOCITY       VELOCITY

   1    391.31          -15.70      -236.68        457.59          391.31      -15.70       -941.70      1019.89         705.03
   2    357.29            3.39       -30.13        358.57          357.29        3.39       -820.74       895.14         790.61
   3    392.64            8.98       -17.07        393.11          392.64        8.98       -871.85       956.23         854.79
   4    453.10           39.35        -8.80        454.89          453.10       39.35       -947.45      1050.96         938.65
   5    510.82           60.61       -15.98        514.65          510.82       60.61      -1020.51      1142.82        1004.53


                  MACH NUMBER                 FLOW ANGLE              TEMPERATURE             PRESSURE              PRESSURE
                                                (DEG)                   (DEG. R)                (PSI)                 RATIO
 STREAM
  LINE     ABSOLUTE   RELATIVE          ABSOLUTE   RELATIVE         TOTAL     STATIC        TOTAL    STATIC        TOT/TOT    TOT/STA

   1          .43        .96             -31.17     -67.44          484.65    467.22        14.009   12.324        2.7282     3.1012
   2          .33        .82              -4.82     -66.48          506.21    495.51        16.488   15.300        2.3181     2.4980
   3          .36        .88              -2.49     -65.76          507.01    494.15        16.387   14.978        2.3323     2.5517
   4          .42        .97              -1.11     -64.45          507.98    490.76        16.502   14.626        2.3160     2.6131
   5          .48       1.06              -1.79     -63.41          507.39    485.35        16.416   14.053        2.3282     2.7196


 STREAM    EQUIVALENT     EQUIVALENT     EQUIV/STATIC
  LINE     TEMPERATURE    INLET          PRESSURE
                          PRESSURE         RATIO
            (DEG. R)      (PSI
   1        553.78         23.629           1.9
   2        562.19         25.010           1.6
   3        570.23         26.377           1.8
   4        582.67         28.589           2.0
   5        594.03         30.706           2.2
```

```
  SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
 NUMBER  NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                 (PSI)        (DEG. R)

   1        3     30000.0         2.600         30.220         626.10

                        OVERALL TURBINE CHARACTERISTICS

 STREAM       PRESSURE RATIO              EFFICIENCY             HEAD        BLADE/JET     THEORETICAL
  LINE     TOT/STA     TOT/TOT      TOT/STA        TOT/TOT    COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1       3.1012      2.7282       .8181          .9067       3.9706         .5018             .4379
   2       2.4980      2.3181       .8325          .8923       2.8019         .5974             .4006
   3       2.5517      2.3323       .8105          .8856       2.5248         .6293             .4707
   4       2.6131      2.3160       .7865          .8848       2.2375         .6685             .5473
   5       2.7198      2.3282       .7630          .8844       2.0751         .6942             .6112

                              MASS AVERAGED QUANTITIES

                            HORSE POWER =      201.29    (HP)
                            MOMENT      =       35.24    (FT-LB)
                            FLOW RATE   =        4.88    (LB/SEC)

                     REFERRED  RPM         =  27296.32
                     REFERRED HORSE POWER =      70.44    (HP)
                     REFERRED MOMENT       =      13.55    (FT-LB)
                     REFERRED FLOW RATE    =       2.06    (LB/SEC)

                 TOTAL/STATIC EFFICIENCY =       .8050
                 TOTAL/TOTAL  EFFICIENCY=        .8908
               TOTAL/STATIC PRESSURE RATIO =    2.6433
               TOTAL/TOTAL  PRESSURE RATIO =    2.3736

              HEAD COEFFICIENT                 =    2.6467
              BLADE/JET SPEED RATIO            =     .6147
              THEORETICAL DEGREE OF REACTION=        .4858
              MACH NUMBER AT STATION 0         =     .2058
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                         SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER             PRESSURE RATIO    PRESSURE      TEMPERATURE
                          1       1     15000.0        2.800          41.160          636.67

                                                              STATOR EXIT SOLUTION

 STREAM    RADIAL      X=R/RM   RADIAL     BLADE      Y=VA./VAM      BLADE         LOSS          ZETA*         FLOW RATE
  LINE    POSITION              SHIFT    OPENING          .        EFFICIENCY   COEFFICIENT   CONTINUITY     FRACTION

            (IN)                 (IN)      (IN)
   1        2.754        .865   0.0000     .2126      1.1050          .9160        .0840         .0840          0.0000
   2        3.003        .940   0.0000     .2347      1.0481          .9091        .0909         .0909           .2504
   3        3.195       1.000    .0290     .2526      1.0000          .9036        .0964         .0964           .4688
   4        3.432       1.074   0.0000     .2745       .9401          .9019        .0981         .0981           .7536
   5        3.627       1.135   0.0000     .2926       .8910          .9005        .0995         .0995          1.0000

                      ABSOLUTE VELOCITY (FPS)                                       RELATIVE VELOCITY (FPS)

 STREAM     AXIAL        RADIAL     TANGENTIAL    OVERALL          AXIAL       RADIAL     TANGENTIAL    OVERALL          WHEEL
  LINE COMPONENT       COMPONENT    COMPONENT     VELOCITY       COMPONENT    COMPONENT   COMPONENT     VELOCITY        VELOCITY

   1     464.88         -18.65       1026.95      1127.43          464.88      -18.65       665.14       811.71          361.81
   2     440.92           4.19        963.20      1059.33          440.92        4.19       570.09       720.72          393.10
   3.    420.70           9.63        910.85      1003.36          420.70        9.63       492.56       647.84          418.29
   4     395.51          34.35        849.46       937.65          395.51       34.35       400.25       563.75          449.20
   5     374.84          44.47        799.73       884.34          374.84       44.47       324.96       498.07          474.77

               MACH NUMBER                 FLOW ANGLE               TEMPERATURE                PRESSURE                 PRESSURE
                                             (DEG)                   (DEG. R)                   (PSI)                    RATIO
 STREAM
  LINE     ABSOLUTE    RELATIVE        ABSOLUTE   RELATIVE        TOTAL      STATIC         TOTAL      STATIC         TOT/TOT     TOT/STA

   1         1.00         .72            65.65      55.05        636.67      530.90         38.586     20.430          1.0667      2.0146
  '2          .93         .63            65.41      52.28        636.67      543.29         38.737     22.235          1.0626      1.8511
   3          .87         .56            65.21      49.50        636.67      552.90         38.878     23.728          1.0587      1.7347
   4          .81         .48            65.04      45.34        636.67      563.51         39.161     25.546          1.0510      1.6112
   5          .75         .42            64.89      40.93        636.67      571.59         39.376     26.999          1.0453      1.5245
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          SET      PAGE        RPM       TOTAL/STATIC      INLET TOTAL    INLET TOTAL
         NUMBER   NUMBER                PRESSURE RATIO     PRESSURE       TEMPERATURE
                                                            (PSI)          (DEG. R)

           1        2      15000.0          2.800          41.160          636.67


                                          ROTOR EXIT SOLUTION


STREAM    RADIAL       X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE        LOSS         ZETA*        FLOW RATE
 LINE     POSITION              SHIFT    OPENING                 EFFICIENCY  COEFFICIENT   CONTINUITY     FRACTION

  1        2.693        .825    .0710     .1912       .9788        .8773        .1227        .1227         0.0000
  2        3.020        .925   -.0168     .2218       .9761        .8768        .1233        .1233          .2333
  3        3.265       1.000   -.0405     .2447      1.0000        .8764        .1237        .1237          .4333
  4        3.585       1.098   -.1537     .2747      1.0619        .8807        .1194        .1194          .7281
  5        3.837       1.175   -.2100     .2983      1.1319        .8841        .1160        .1160         1.0000

                 ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL    TANGENTIAL    OVERALL        WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT    VELOCITY      VELOCITY

  1     430.45       -17.27      -683.39       807.84        430.45      -17.27     -1035.90     1121.91        352.51
  2     429.27         4.08      -590.78       730.28        429.27        4.08      -986.08     1075.48        395.31
  3     439.79        10.06      -549.15       703.62        439.79       10.06      -976.54     1071.05        427.39
  4     467.02        40.56      -507.24       690.69        467.02       40.56      -976.57     1083.25        469.33
  5     497.79        59.06      -492.21       702.53        497.79       59.06      -994.47     1113.66        502.26

            MACH NUMBER              FLOW ANGLE            TEMPERATURE             PRESSURE              PRESSURE
                                       (DEG)                (DEG. R)                (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE   RELATIVE     TOTAL     STATIC       TOTAL     STATIC       TOT/TOT    TOT/STA

  1         .75       1.04        -57.80     -67.44      534.74    480.44       18.800    12.923       2.1894     3.1849
  2         .67        .99        -54.00     -66.48      534.79    490.41       19.078    14.088       2.1575     2.9216
  3         .65        .98        -51.31     -65.76      534.20    493.01       19.092    14.417       2.1559     2.8550
  4         .63        .99        -47.37     -64.45      533.55    493.85       19.186    14.637       2.1454     2.8120
  5         .65       1.03        -44.68     -63.41      532.34    491.27       19.086    14.410       2.1565     2.8563


STREAM   EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE     TEMPERATURE     INLET         PRESSURE
                        PRESSURE        RATIO
          (DEG. R)       (PSI
  1       585.17        28.723          2.2
  2       586.66        29.092          2.1
  3       588.46        29.513          2.0
  4       591.50        30.268          2.1
  5       594.47        30.974          2.1
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   SET     PAGE      RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
  NUMBER  NUMBER             PRESSURE RATIO   PRESSURE     TEMPERATURE
                                               (PSI)        (DEG. R)

    1       3     15000.0        2.800        41.160        636.67


                        OVERALL TURBINE CHARACTERISTICS


STREAM      PRESSURE RATIO           EFFICIENCY          HEAD       BLADE/JET      THEORETICAL
 LINE    TOT/STA    TOT/TOT     TOT/STA     TOT/TOT    COEFFICIENT  SPEED RATIO DEGREE OF REACTION

   1     3.1849     2.1894      .5682       .7981      16.4689       .2464          .3563
   2     2.9216     2.1575      .6065       .8113      13.0634       .2767          .3885
   3     2.8550     2.1559      .6215       .8167      11.3249       .2972          .4377
   4     2.8120     2.1454      .6333       .8267       9.6977       .3211          .5018
   5     2.8563     2.1565      .6325       .8313       8.7936       .3372          .5619


                              MASS AVERAGED QUANTITIES


                             HORSE POWER =      182.97    (HP)
                             MOMENT      =       64.06    (FT-LB)
                             FLOW RATE   =        5.25    (LB/SEC)

                  REFERRED  RPM          =  13535.26
                  REFERRED HORSE POWER   =      50.96     (HP)
                  REFERRED MOMENT        =      22.88     (FT-LB)
                  REFERRED FLOW RATE     =       2.08     (LB/SEC)

              TOTAL/STATIC EFFICIENCY    =       .6154
              TOTAL/TOTAL  EFFICIENCY=           .8174
           TOTAL/STATIC PRESSURE RATIO   =      2.9023
           TOTAL/TOTAL  PRESSURE RATIO   =      2.1579

         HEAD COEFFICIENT                =     11.6793
         BLADE/JET SPEED RATIO           =       .2926
         THEORETICAL DEGREE OF REACTION=         .4468
         MACH NUMBER AT STATION 0        =       .2072
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                  SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                NUMBER   NUMBER              PRESSURE RATIO    PRESSURE     TEMPERATURE
                  1        1      20000.0        2.800          41.160         636.67


                                                 STATOR EXIT SOLUTION


STREAM    RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE       LOSS        ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING                EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

           (IN)                (IN)      (IN)
  1        2.764       .865   0.0000     .2126      1.1018       .9146       .0054        .0054        0.0000
  2        3.003       .940   0.0000     .2347      1.0470       .9117       .0883        .0883         .2509
  3        3.195      1.000    .0290     .2526      1.0000       .9094       .0906        .0906         .4698
  4        3.432      1.074   0.0000     .2745       .9400       .9071       .0929        .0929         .7546
  5        3.627      1.135   0.0000     .2926       .8902       .9052       .0948        .0948        1.0000

                 ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

STREAM    AXIAL      RADIAL     TANGENTIAL   OVERALL       AXIAL      RADIAL     TANGENTIAL    OVERALL        WHEEL
 LINE COMPONENT    COMPONENT    COMPONENT    VELOCITY    COMPONENT  COMPONENT    COMPONENT     VELOCITY      VELOCITY

  1     450.26      -18.06       994.65      1091.97      450.26     -18.06        512.24       682.24        482.41
  2     427.89        4.06       934.73      1028.02      427.89       4.06        410.59       593.04        524.14
  3     408.68        9.35       884.83       974.69      408.68       9.35        327.11       523.55        557.72
  4     384.14       33.36       825.04       910.70      384.14      33.36        226.10       446.99        598.94
  5     363.79       43.16       776.17       858.29      363.79      43.16        143.14       393.32        633.03

            MACH NUMBER             FLOW ANGLE              TEMPERATURE              PRESSURE              PRESSURE
                                      (DEG)                  (DEG. R)                 (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE  RELATIVE       TOTAL     STATIC        TOTAL     STATIC       TOT/TOT    TOT/STA

  1         .96        .60         65.65     48.69        636.67    537.45        38.729    21.405       1.0628     1.9229
  2         .90        .52         65.41     43.82        636.67    548.73        30.967    23.161       1.0563     1.7771
  3         .84        .45         65.21     38.68        636.67    557.62        39.161    24.622       1.0510     1.6717
  4         .78        .38         65.04     30.48        636.67    567.66        39.394    26.365       1.0448     1.5611
  5         .73        .33         64.89     21.48        636.67    575.37        39.575    27.768       1.0400     1.4823
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      SET    PAGE        RPM      TOTAL/STATIC    INLET TOTAL   INLET TOTAL
    NUMBER  NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                    (PSI)        (DEG. R)

       1       2      20000.0         2.800         41.160        636.67

                                         ROTOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM     BLADE      LOSS          ZETA*         FLOW RATE
 LINE    POSITION               SHIFT     OPENING                EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

   1       2.693        .825     .0710     .1912       .9833       .8933       .1067         .1067         0.0000
   2       3.020        .925   -.0168      .2218       .9561       .8963       .1037         .1037          .2288
   3       3.265       1.000   -.0405      .2447      1.0000       .8985       .1015         .1015          .4274
   4       3.585       1.098   -.1537      .2747      1.0908       .9038       .0962         .0962          .7235
   5       3.837       1.175   -.2100      .2983      1.1853       .9080       .0920         .0920         1.0000

              ABSOLUTE VELOCITY (FPS)                                 RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL    OVERALL       AXIAL       RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE  COMPONENT    COMPONENT    COMPONENT     VELOCITY    COMPONENT   COMPONENT    COMPONENT    VELOCITY      VELOCITY

   1     413.86      -16.60      -525.94      669.45       413.86      -16.60      -995.95      1078.65       470.02
   2     402.41        3.82      -397.32      565.52       402.41        3.82      -924.39      1008.19       527.07
   3     420.89        9.63      -364.72      557.01       420.89        9.63      -934.57      1025.02       569.85
   4     459.09       39.87      -334.21      569.26       459.09       39.87      -959.98      1064.86       625.77
   5     498.88       59.19      -326.97      599.41       498.88       59.19      -996.65      1116.11       669.68

           MACH NUMBER              FLOW ANGLE             TEMPERATURE            PRESSURE              PRESSURE
                                      (DEG)                 (DEG. R)               (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE  RELATIVE     ABSOLUTE  RELATIVE       TOTAL    STATIC       TOTAL    STATIC        TOT/TOT   TOT/STA

   1        .62      1.01       -51.80    -67.44        515.68   470.38       17.000   13.072        2.4211    3.1486
   2        .52       .93       -44.64    -66.48        520.28   493.67       17.922   14.914        2.2966    2.7599
   3        .51       .94       -40.91    -65.76        519.95   494.14       17.961   15.029        2.2916    2.7388
   4        .52       .98       -36.06    -64.45        519.63   492.66       18.003   14.940        2.2863    2.7551
   5        .55      1.03       -33.24    -63.41        518.46   488.56       17.872   14.517        2.3031    2.8352

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
   1      575.20       27.146         2.1
   2      578.25       27.823         1.9
   3      581.56       28.526         1.9
   4      587.02       29.649         2.0
   5      592.22       30.719         2.1
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            SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
          NUMBER   NUMBER               PRESSURE RATIO    PRESSURE     TEMPERATURE
                                                            (PSI)       (DEG. R)

             1        3     20000.0          2.800          41.160        636.67


                                 OVERALL TURBINE CHARACTERISTICS

STREAM        PRESSURE RATIO           EFFICIENCY            HEAD        BLADE/JET      THEORETICAL
 LINE      TOT/STA    TOT/TOT      TOT/STA    TOT/TOT     COEFFICIENT   SPEED RATIO DEGREE OF REACTION

   1       3.1486     2.4211        .6802      .8513        9.1863         .3299            .3902
   2       2.7599     2.2966        .7261      .8646        7.0119         .3776            .3982
   3       2.7388     2.2916        .7329      .8691        6.1525         .4032            .4541
   4       2.7551     2.2863        .7313      .8737        5.3619         .4319            .5247
   5       2.8352     2.3031        .7211      .8755        4.9165         .4510            .5869


                                       MASS AVERAGED QUANTITIES


                                    HORSE POWER =      200.91    (HP)
                                    MOMENT      =       54.86    (FT-LB)
                                    FLOW RATE   =        5.24    (LB/SEC)

                          REFERRED  RPM         =    18047.01
                          REFERRED HORSE POWER  =       67.32    (HP)
                          REFERRED MOMENT       =       19.59    (FT-LB)
                          REFERRED FLOW RATE    =        2.07    (LB/SEC)

                     TOTAL/STATIC EFFICIENCY =          .7227
                     TOTAL/TOTAL  EFFICIENCY=           .8677
                 TOTAL/STATIC PRESSURE RATIO =         2.8114
                 TOTAL/TOTAL  PRESSURE RATIO =         2.3092

               HEAD COEFFICIENT                =       6.3944
               BLADE/JET SPEED RATIO           =        .3955
               THEORETICAL DEGREE OF REACTION=          .4664
               MACH NUMBER AT STATION 0        =        .2069
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      SET      PAGE        RPM       TOTAL/STATIC     INLET TOTAL   INLET TOTAL
    NUMBER    NUMBER                PRESSURE RATIO   PRESSURE      TEMPERATURE
       1         1      25000.0         2.800          41.160          636.67

                                              STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL    BLADE     Y=VA /VAM      BLADE       LOSS        ZETA*       FLOW RATE
 LINE    POSITION               SHIFT   OPENING                 EFFICIENCY  COEFFICIENT  CONTINUITY   FRACTION

           (IN)                 (IN)     (IN)
   1      2.764         .865   0.0000    .2126      1.1033        .9178       .0822        .0822       0.0000
   2      3.003         .940   0.0000    .2347      1.0476        .9139       .0861        .0861        .2527
   3      3.195        1.000    .0290    .2526      1.0000        .9108       .0892        .0892        .4721
   4      3.432        1.074   0.0000    .2745       .9396        .9085       .0915        .0915        .7562
   5      3.627        1.135   0.0000    .2926       .8897        .9065       .0935        .0935       1.0000

                         ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL     TANGENTIAL   OVERALL          AXIAL       RADIAL     TANGENTIAL   OVERALL        WHEEL
 LINE COMPONENT     COMPONENT    COMPONENT    VELOCITY        COMPONENT   COMPONENT   COMPONENT    VELOCITY       VELOCITY

   1    434.12        -17.41       958.99     1052.81          434.12      -17.41       355.97      561.67         603.01
   2    412.21          3.92       900.48      990.35          412.21        3.92       245.31      479.70         655.17
   3    393.49          9.00       851.94      938.46          393.49        9.00       154.79      422.93         697.15
   4    369.73         32.11       794.09      876.54          369.73       32.11        45.42      373.89         748.67
   5    350.09         41.54       746.93      825.95          350.09       41.54       -44.36      355.32         791.29

              MACH NUMBER            FLOW ANGLE           TEMPERATURE           PRESSURE              PRESSURE
                                       (DEG)               (DEG. R)               (PSI)                  RATIO
STREAM
 LINE     ABSOLUTE  RELATIVE      ABSOLUTE  RELATIVE      TOTAL    STATIC       TOTAL    STATIC       TOT/TOT   TOT/STA

   1         .92       .49          65.65     39.35       636.67   544.44       39.017   22.561       1.0549    1.8244
   2         .86       .42          65.41     30.76       636.67   555.06       39.199   24.253       1.0500    1.6971
   3         .81       .36          65.21     21.47       636.67   563.38       39.353   25.651       1.0459    1.6046
   4         .75       .32          65.04      7.00       636.67   572.74       39.562   27.316       1.0404    1.5068
   5         .70       .30          64.89     -7.22       636.67   579.90       39.724   28.648       1.0361    1.4367
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                    SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                   NUMBER  NUMBER               PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                  (PSI)         (DEG. R)

                     1        2     25000.0         2.800         41.160        636.67

                                                    ROTOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM   RADIAL    BLADE     Y=VA /VAM    BLADE       LOSS          ZETA*         FLOW RATE
 LINE    POSITION              SHIFT    OPENING               EFFICIENCY  COEFFICIENT   CONTINUITY    FRACTION

   1       2.693       .825    .0710     .1912      .9888       .9114        .0886         .0886       0.0000
   2       3.020       .925   -.0168     .2218      .9357       .9126        .0875         .0875        .2258
   3       3.265      1.000   -.0405     .2447     1.0000       .9134        .0866         .0866        .4237
   4       3.585      1.098   -.1537     .2747     1.1196       .9075        .0926         .0926        .7210
   5       3.837      1.175   -.2100     .2983     1.2386       .9028        .0972         .0972       1.0000

                 ABSOLUTE VELOCITY (FPS)                                RELATIVE VELOCITY (FPS)

STREAM     AXIAL       RADIAL     TANGENTIAL    OVERALL        AXIAL      RADIAL    TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY     COMPONENT  COMPONENT   COMPONENT     VELOCITY     VELOCITY

   1     411.06       -16.49       -401.70       574.98       411.06     -16.49      -989.22      1071.35       587.52
   2     388.97         3.70       -234.66       454.28       388.97       3.70      -893.50       974.50       658.84
   3     415.71         9.51       -210.75       466.18       415.71       9.51      -923.07      1012.40       712.31
   4     465.42        40.42       -190.99       504.70       465.42      40.42      -973.20      1079.52       782.21
   5     514.87        61.09       -191.50       552.72       514.87      61.09     -1028.61      1151.90       837.11

              MACH NUMBER              FLOW ANGLE              TEMPERATURE            PRESSURE              PRESSURE
                                         (DEG)                   (DEG. R)              (PSI)                 RATIO
STREAM
 LINE     ABSOLUTE   RELATIVE      ABSOLUTE  RELATIVE        TOTAL     STATIC       TOTAL    STATIC      TOT/TOT    TOT/STA

  1          .54       1.00         -44.34    -67.44         501.15    473.64       15.752   12.928       2.6130     3.1838
  2          .42        .89         -31.10    -66.48         512.76    495.58       17.412   15.455       2.3639     2.6632
  3          .43        .93         -26.89    -65.76         512.84    494.76       17.425   15.367       2.3622     2.6784
  4          .46        .99         -22.31    -64.45         512.87    491.67       17.286   14.912       2.3811     2.7601
  5          .51       1.07         -20.40    -63.41         511.63    486.21       16.946   14.178       2.4289     2.9032

STREAM   EQUIVALENT   EQUIVALENT   EQUIV/STATIC
LINE     TEMPERATURE   INLET        PRESSURE
                       PRESSURE      RATIO
          (DEG. R)     (PSI
  1       569.15       26.354        2.0
  2       574.60       27.376        1.8
  3       580.05       28.405        1.8
  4       588.64       30.065        2.0
  5       596.62       31.644        2.2
```

```
                         SET     PAGE        RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
                        NUMBER  NUMBER              PRESSURE RATIO   PRESSURE      TEMPERATURE
                                                                       (PSI)         (DEG. R)

                          1       3     25000.0          2.800         41.160        636.67


                                         OVERALL TURBINE CHARACTERISTICS


 STREAM       PRESSURE RATIO             EFFICIENCY              HEAD          BLADE/JET      THEORETICAL
  LINE     TOT/STA     TOT/TOT      TOT/STA      TOT/TOT      COEFFICIENT    SPEED RATIO DEGREE OF REACTION

   1       3.1838      2.6130        .7556        .8870         5.9273          .4107            .4397
   2       2.6632      2.3639        .7973        .8931         4.3511          .4794            .4254
   3       2.6784      2.3622        .7928        .8932         3.8622          .5088            .4848
   4       2.7601      2.3811        .7723        .8858         3.4370          .5394            .5610
   5       2.9032      2.4289        .7482        .8770         3.2078          .5583            .6253


                                              MASS AVERAGED QUANTITIES


                                          HORSE POWER =     221.79   (HP)
                                          MOMENT      =      46.59   (FT-LB)
                                          FLOW RATE   =       5.21   (LB/SEC)


                                 REFERRED  RPM         =  22558.76
                                 REFERRED HORSE POWER =      71.48   (HP)
                                 REFERRED MOMENT      =      16.64   (FT-LB)
                                 REFERRED FLOW RATE   =       2.06   (LB/SEC)


                              TOTAL/STATIC EFFICIENCY =      .7786
                              TOTAL/TOTAL  EFFICIENCY=       .8885
                           TOTAL/STATIC PRESSURE RATIO =    2.7063
                           TOTAL/TOTAL  PRESSURE RATIO =    2.4070


                          HEAD COEFFICIENT             =    4.0544
                          BLADE/JET SPEED RATIO        =     .4966
                          THEORETICAL DEGREE OF REACTION=    .5009
                          MACH NUMBER AT STATION 0     =     .2058
```

```
          SET      PAGE        RPM       TOTAL/STATIC      INLET TOTAL   INLET TOTAL
         NUMBER   NUMBER                PRESSURE RATIO    PRESSURE      TEMPERATURE
           1        1       30000.0         2.800          41.160          636.67

                                             STATOR EXIT SOLUTION

STREAM    RADIAL       X=R/RM   RADIAL     BLADE      Y=VA /VAM     BLADE        LOSS        ZETA*        FLOW RATE
 LINE    POSITION               SHIFT    OPENING                 EFFICIENCY   COEFFICIENT  CONTINUITY    FRACTION

          (IN)                  (IN)      (IN)
  1       2.764       .865    0.0000     .2126      1.1042        .9209         .0791        .0791        0.0000
  2       3.003       .940    0.0000     .2347      1.0480        .9164         .0836        .0836         .2529
  3       3.195      1.000     .0290     .2526      1.0000        .9127         .0873        .0873         .4724
  4       3.432      1.074    0.0000     .2745       .9393        .9101         .0899        .0899         .7563
  5       3.627      1.135    0.0000     .2926       .8891        .9079         .0921        .0921        1.0000

                   ABSOLUTE VELOCITY (FPS)                                  RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL      TANGENTIAL    OVERALL         AXIAL       RADIAL      TANGENTIAL    OVERALL         WHEEL
 LINE COMPONENT      COMPONENT    COMPONENT     VELOCITY      COMPONENT    COMPONENT    COMPONENT     VELOCITY       VELOCITY

  1    434.48         -17.43       959.78       1053.69        434.48       -17.43        236.17       494.82         723.62
  2    412.35           3.92       900.77        990.68        412.35         3.92        114.57       427.98         786.21
  3    393.47           9.00       851.90        938.42        393.47         9.00         15.31       393.87         836.58
  4    369.58          32.10       793.76        876.17        369.58        32.10       -104.65       385.45         898.41
  5    349.84          41.51       746.41        825.37        349.84        41.51       -203.14       406.67         949.55

             MACH NUMBER               FLOW ANGLE               TEMPERATURE              PRESSURE               PRESSURE
                                         (DEG)                   (DEG. R)                  (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE      ABSOLUTE   RELATIVE         TOTAL     STATIC         TOTAL     STATIC        TOT/TOT     TOT/STA

  1         .92        .43          65.65      28.53          636.67    544.28         39.097    22.585        1.0528      1.8224
  2         .86        .37          65.41      15.53          636.67    555.00         39.257    24.280        1.0485      1.6952
  3         .81        .34          65.21       2.23          636.67    563.39         39.396    25.680        1.0448      1.6028
  4         .75        .33          65.04     -15.81          636.67    572.79         39.594    27.348        1.0395      1.5051
  5         .70        .34          64.89     -30.14          636.67    579.98         39.749    28.680        1.0355      1.4352
```

```
     SET      PAGE        RPM       TOTAL/STATIC     INLET TOTAL    INLET TOTAL
    NUMBER   NUMBER                PRESSURE RATIO    PRESSURE      TEMPERATURE
                                                       (PSI)         (DEG. R)

      1         2     30000.0          2.800          41.160          636.67

                                           ROTOR EXIT SOLUTION

STREAM    RADIAL      X=R/RM   RADIAL    BLADE      Y=VA /VAM     BLADE      LOSS         ZETA*        FLOW RATE
 LINE    POSITION              SHIFT    OPENING                EFFICIENCY  COEFFICIENT  CONTINUITY    FRACTION

   1       2.693        .825    .0710    .1912        .9952       .9230       .0770        .0770        0.0000
   2       3.020        .925   -.0168    .2210        .9151       .9084       .0916        .0916         .2210
   3       3.265       1.000   -.0405    .2447       1.0000       .8975       .1025        .1025         .4152
   4       3.585       1.098   -.1537    .2747       1.1467       .9052       .0949        .0949         .7126
   5       3.837       1.175   -.2100    .2983       1.2872       .9112       .0888        .0880        1.0000

                  ABSOLUTE VELOCITY (FPS)                                    RELATIVE VELOCITY (FPS)

STREAM    AXIAL       RADIAL      TANGENTIAL    OVERALL        AXIAL      RADIAL     TANGENTIAL    OVERALL       WHEEL
 LINE COMPONENT     COMPONENT     COMPONENT     VELOCITY     COMPONENT   COMPONENT   COMPONENT     VELOCITY     VELOCITY

   1    409.70        -16.43       -280.93       497.03        409.70     -16.43      -985.95      1067.81       705.03
   2    376.73          3.58        -74.78       384.09        376.73       3.58      -865.39       943.84       790.61
   3    411.68          9.42        -59.36       416.05        411.60       9.42      -914.14      1002.61       854.78
   4    472.07         41.00        -48.47       476.32        472.07      41.00      -987.13      1094.97       938.65
   5    529.93         62.87        -54.16       536.39        529.93      62.87     -1058.69      1185.58      1004.53

          MACH NUMBER              FLOW ANGLE             TEMPERATURE              PRESSURE               PRESSURE
                                     (DEG)                  (DEG. R)                (PSI)                  RATIO
STREAM
 LINE    ABSOLUTE   RELATIVE     ABSOLUTE  RELATIVE      TOTAL     STATIC       TOTAL     STATIC       TOT/TOT     TOT/STA

   1        .47       1.01        -34.44    -67.44       488.13    467.57       14.532    12.501       2.8323      3.2926
   2        .35        .86        -11.23    -66.48       508.97    496.69       17.006    15.613       2.4204      2.6363
   3        .38        .92         -8.21    -65.76       509.62    495.22       16.885    15.272       2.4377      2.6950
   4        .44       1.01         -5.86    -64.45       510.42    491.54       16.943    14.849       2.4293      2.7719
   5        .50       1.10         -5.84    -63.41       509.66    485.72       16.788    14.186       2.4517      2.9014

STREAM   EQUIVALENT    EQUIVALENT    EQUIV/STATIC
LINE     TEMPERATURE    INLET         PRESSURE
                        PRESSURE        RATIO
          (DEG. R)      (PSI
  1       562.45        25.336          2.0
  2       570.82        26.790          1.7
  3       578.86        28.233          1.8
  4       591.31        30.569          2.1
  5       602.68        32.805          2.3
```

```
   SET     PAGE       RPM      TOTAL/STATIC     INLET TOTAL   INLET TOTAL
  NUMBER  NUMBER             PRESSURE RATIO     PRESSURE     TEMPERATURE
                                                  (PSI)        (DEG. R)

     1       3    30000.0         2.800          41.160         636.67

                          OVERALL TURBINE CHARACTERISTICS

STREAM       PRESSURE RATIO          EFFICIENCY          HEAD       BLADE/JET     THEORETICAL
 LINE     TOT/STA    TOT/TOT     TOT/STA     TOT/TOT   COEFFICIENT  SPEED RATIO DEGREE OF REACTION

   1      3.2926     2.8323       .8085       .9068      4.2165        .4870          .4539
   2      2.6363     2.4204       .8291       .8987      2.9944        .5779          .4213
   3      2.6950     2.4377       .8090       .8879      2.6966        .6090          .4808
   4      2.7719     2.4293       .7847       .8853      2.3954        .6461          .5637
   5      2.9014     2.4517       .7603       .8826      2.2265        .6702          .6262

                                 MASS AVERAGED QUANTITIES

                               HORSE POWER =     229.28   (HP)
                               MOMENT      =      40.14   (FT-LB)
                               FLOW RATE   =       5.22   (LB/SEC)

                          REFERRED  RPM        =  27070.52
                          REFERRED HORSE POWER =     73.89   (HP)
                          REFERRED MOMENT      =     14.34   (FT-LB)
                          REFERRED FLOW RATE   =      2.07   (LB/SEC)

                       TOTAL/STATIC EFFICIENCY =      .8018
                       TOTAL/TOTAL  EFFICIENCY=       .8917
                    TOTAL/STATIC PRESSURE RATIO =    2.8001
                    TOTAL/TOTAL  PRESSURE RATIO =    2.4824

                  HEAD COEFFICIENT               =    2.8270
                  BLADE/JET SPEED RATIO          =     .5948
                  THEORETICAL DEGREE OF REACTION=      .5035
                  MACH NUMBER AT STATION 0       =     .2062
```

APPENDIX: G

COMPUTER LISTING

```
&MAIN  T=00004 IS ON CR00025 USING 00147 BLKS R=0000

FTN4,L
      BLOCK DATA
      COMMON/ABA/BA17,BLEX
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/TRS/TRAS
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/MAC/IN
      COMMON/IWT/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/CSS/CJ,G,Q1
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR,VU1(10)
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/VAR5/PRAT1(10),RINCI(10),ALFA11(10),BETA11(10),ZETA1(10),
     *V2(10),ALFA22(10),BETA22(10)
      COMMON/VAR6/PT2(10),TT2(10),PT1(10),DELH(10),ALFA2(10),VU2(10),
     *WR2(10),T2S(10),T2IS(10)
      COMMON/VAR7/TTIS(5),BETAT(5),ETAT(5),ETAI(10),ETAS(10),ETAR(10),
     *RSTAR(10),AKIS(10),PSIR(10)
      COMMON/VAR8/DR1(10),AMW1(10),AMV2(10),BETET(10),PRAT1T(10),AMR2(
     *10),YS(10),X1(10),AREA1(10),ZETAPS(10),WPER1(10),YR(10),X2(10)
      COMMON/VAR9/ZETAR(10),ZETAPR(10),AS(10),AR(10),SI1(10),SI2(10),
     *S1(10),DSDX1(10),WI1(10),HE(10)
      COMMON/VAR10/WU1(10),DHEDX(10),DSDX2(10),RI1(10),RI2(10),
     *RI3(10),RI4(10),RI(10),SR1(10),SR2(10)
      COMMON/VAR11/YOLD(10),AA(10),SR(10),PRAT2(10),WPER2(10),
     *DWDX(10),T1IS(10),PRAT3(10),SS(10),ALFA(10)
      COMMON/VAR12/BETA(10),DELR(10),WPERO(10),ZETAS(10),ZETAR1(20),
     *ZETAR3(20),ZETAR5(20),R1(20),A1(20),T10(20)
      COMMON/VAR13/ST1(20),IRR(20),R2(20),A2(20),RINC(20),DR(10),
     *BETO(10),STALII(10),AREA2(10),VR1(10)
      COMMON/VAR14/WLBM,PRAT5,OMEG
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG2O,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,J,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETAO(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WU2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,IR,TOR,STALI(10)
      COMMON/ARE/REE
      COMMON/TRA/XP01(5,8),XP02(6,8),ALF1(8),ALF01(5),ALF02(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      DATA ALF1/ 10.,15.,20.,25.,30.,40.,50.,60./
      DATA ALF01/ 40.,50.,60.,70.,80./
      DATA ALF02/ 80.,90.,100.,120.,150.,170./
      DATA XP01/  .0570,.0465,.0440,.0428,.0424,
     *            .0530,.0415,.0350,.0330,.0323,
     *            .0495,.0380,.0312,.0296,.0285,
     *            .0475,.0355,.0295,.0267,.0250,
     *            .0440,.0335,.0273,.0245,.0225,
     *            .0420,.0312,.0224,.0205,.0183,
     *            .0420,.0300,.0213,.0181,.0152,
     *            .0420,.0300,.0206,.0155,.0125/
      DATA XP02/  .0424,.0422,.0420,.0402,.0313,.0000,
     *            .0323,.0320,.0318,.0295,.0200,.0000,
     *            .0283,.0280,.0275,.0250,.0143,.0000,
     *            .0250,.0246,.0242,.0208,.0070,.0000,
     *            .0225,.0216,.0203,.0168,.0000,.0000,
     *            .0183,.0170,.0154,.0106,.0100,.0000,
     *            .0150,.0136,.0104,.0050,-.015,.0000,
     *            .0125,.0099,.0073,.0000,-.020,.0000/
      DATA VIS2,VIS3,CP,EMMF,GAM/.000013,.000012,.24,28.97,1.4/
      DATA G,CJ,EXP1,EXP2,ERRE/32.174,778.16,3.5,.2857,53.3459/
      END
      PROGRAM THESS
C
C
      DIMENSION INAM(3)
      COMMON/ABA/BA17,BLEX
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/TRS/TRAS
      COMMON/GAS/CP,GAM,EMMF,ERRE,EXP1,EXP2,VIS2,VIS3
```

```
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/MAC/IN
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/CSS/CJ,G,Q1
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR,VU1(10)
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/VAR5/PRA11(10),RINCI(10),ALFA11(10),BETA11(10),ZETA1(10),
     *V2(10),ALFA22(10),BETA22(10)
      COMMON/VAR6/PT2(10),TT2(10),PT1(10),DELH(10),ALFA2(10),VU2(10),
     *WR2(10),T2S(10),T2IS(10)
      COMMON/VAR7/TTIS(5),BETAT(5),ETAT(5),ETAI(10),ETAS(10),ETAR(10),
     *RSTAR(10),AKIS(10),PSTR(10)
      COMMON/VAR8/DR1(10),AMW1(10),AMV2(10),BETET(10),PRAT1T(10),
     *AMR2(10),YS(10),X1(10),AREA1(10),ZETAPS(10),WPER1(10),YR(10),
     *X2(10)
      COMMON/VAR9/ZETAR(10),ZETAPR(10),AS(10),AR(10),SI1(10),SI2(10),
     *S1(10),DSDX1(10),WI1(10),HE(10)
      COMMON/VAR10/WU1(10),DHEDX(10),DSDX2(10),RI1(10),RI2(10),
     *RI3(10),RI4(10),RI(10),SR1(10),SR2(10)
      COMMON/VAR11/YOLD(10),AA(10),SR(10),PRAT2(10),WPER2(10),
     *DWDX(10),T1IS(10),PRAT3(10),SS(10),ALFA(10)
      COMMON/VAR12/BETA(10),DELR(10),WPERO(10),ZETAS(10),ZETAR1(20),
     *ZETAR3(20),ZETAR5(20),R1(20),A1(20),T10(20)
      COMMON/VAR13/ST1(20),IRR(20),R2(20),A2(20),RINC(20),DR(10),
     *BETO(10),STALII(10),AREA2(10),VR1(10)
      COMMON/VAR14/WLBM,PRATS,OMEG
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,RESP,XX,ANG20,AMS1(10),S,TN,C,TF,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D10,D2I,D20,ANG2I,ALFAX,TI,T,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETA0(10),W2(10),TTE(10),U2(10),
     *STR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WU2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STAL1(10)
      COMMON/ARF/REE
      COMMON/TRA/XP01(5,8),XP02(6,8),ALF1(8),ALF01(5),ALF02(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      DATA INAM /2HSH,2HOR,2HT /
      TRAS=1
      XX=1.25
      CALL EXEC(8,INAM)
      END
C
      SUBROUTINE CHAN(TTO,AMC,PTO,RC,WLBM,WCHAN,WPERO)
      DIMENSION RC(10),WPERO(10)
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/CSS/CJ,G,Q1
      TC=TTO/(1.+(GAM-1.)/2.*AMC*AMC)
      VC=SQRT(GAM*ERRE*G*TC)*AMC
      PC=PTO/(1.+(GAM-1.)*AMC**2/2.)**EXP1
      RHO=PC/ERRE/TC
      AREA=3.1416*(RC(5)**2-RC(1)**2)
      WLBM=RHO*AREA*VC
      WCHAN=WLBM/(PTO*SQRT(G/ERRE/TTO))
      WPERO(1)=0.
      WPERO(2)=.25
      WPERO(3)=.5
      WPERO(4)=.75
      WPERO(5)=1.0
      RETURN
      END
C
      SUBROUTINE STATR  (ALFA1,X,TTO,PTO,AM,T,P,V1,VA1,SI1,SI2,Y,S,DSDX,
     *VU1,PRAT,T1IS,SS,DALF,RSF,DELR,CL,CK,ZETAPS,R,RS1,RS3,RS5,
     *ZETA,DR,ZETAS,AMS,NS,VR1)
      DIMENSION ALFA1(10),X(10),T(10),P(10),V1(10),VA1(10),SI1(10),
     *SI2(10),Y(10),DSDX(10),VU1(10),PRAT(10),T1IS(10),SS(10),S(10),
     *DALDX(10),ALFA(10),ALFAM(10),DALF(10),AMS(10),DALFDX(10),DELR(
     *10),ZETAS(10),ETA(10),ZETAPS(10),R(10),ZETA(10),DR(10),VR1(10)
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/CSS/CJ,G,Q1
      COMMON/IWI/IND,INZ,IWR
      C8=0.0
      C9=0.0
      Q1=2.*CJ*G*CP
      C2=VA1(3)**2/(Q1*TTO)
```

```
      DO 303 I=1,5
      IF(R(I)-RS3) 300,301,302
  300 ZETAS(I)=ZETA(1)+((R(I)-RS1)/(RS3-RS1))*(ZETA(3)-ZETA(1))
      ALFA1(I)=ALFA1(3)+((R(I)-RS3)/(RS1-RS3))*DALF(1)
      ZETAPS(I)=ZETAPS(1)+((R(I)-RS1)/(RS3-RS1))*(ZETAPS(3)-ZETAPS(1))
      GO TO 303
  301 ZETAS(I)=ZETA(3)
      ALFA1(I)=ALFA1(3)
      GO TO 303
  302 ZETAS(I)=ZETA(3)+((R(I)-RS3)/(RS5-RS3))*(ZETA(5)-ZETA(3))
      ALFA1(I)=ALFA1(3)+((R(I)-RS3)/(RS5-RS3))*DALF(5)
      ZETAPS(I)=ZETAPS(3)+((R(I)-RS3)/(RS5-RS3))*(ZETAPS(5)-ZETAPS(3))
  303 CONTINUE
      DO 305 I=1,5
      ETA(I)=1.-ZETAS(I)
      M=I-1
      N=I+1
      IF(I-1) 307,307,309
  307 DALFDX(1)=(ALFA1(2)-ALFA1(1))/(X(2)-X(1))
      GO TO 315
  309 IF(I-5) 311,313,313
  311 DALFDX(I)=.5*((ALFA1(N)-ALFA1(I))/(X(N)-X(I))+(ALFA1(I)-ALFA1(M))/
     *(X(I)-X(M)))
      GO TO 315
  313 DALFDX(5)=(ALFA1(5)-ALFA1(4))/(X(5)-X(4))
  315 TAN1=-2.*TAN(ALFA1(I))
      PROD=TAN1*DALFDX(I)
      SINSQ=-2.*SIN(ALFA1(I))**2/X(I)
      SI1(I)=PROD+SINSQ
  305 CONTINUE
  304 DO 332 J=1,5
      IF(J-1) 306,306,310
  306 IF(NS-1) 317,310,310
  317 DO 308 I=1,5
      SS(I)=0.
  308 SI2(I)=SI1(I)
      GO TO 318
  310 DO 312 I=1,5
      AA=C2*Y(I)**2/COS(ALFA1(I))**2
      AB=(1.-AA)/(1.-AA/ETA(I))
  312 S(I)=ALOG(AB)
  314 DSDX(1)=(S(2)-S(1))/(X(2)-X(1))
      DSDX(2)=0.5*(DSDX(1)+(S(3)-S(2))/(X(3)-X(2)))
      DSDX(3)=.5*((S(4)-S(3))/(X(4)-X(3))+(S(3)-S(2))/(X(3)-X(2)))
      DSDX(4)=.5*((S(5)-S(4))/(X(5)-X(4))+(S(4)-S(3))/(X(4)-X(3)))
      DSDX(5)=(S(5)-S(4))/(X(5)-X(4))
      DO 316 I=1,5
      IF(NS-1) 319,321,321
  319 SS(I)=(1.-COS(ALFA1(I))**2/(C2*Y(I)**2))*DSDX(I)
      GO TO 316
  321 SS(I)=((-COS(ALFA1(I))**2/(C2*Y(I)**2))+SIN(ALFA1(I))**2+COS(AL
     *FA1(I))**2*(CL**2+(DR(I)/2.0)**2)/CL**2)*DSDX(I)+COS(ALFA1(I))**2*
     *CK*2.*RSF*DELR(I)/CL**2
  316 SI2(I)=SS(I)+SI1(I)
  318 SUM1=(SI2(1)+SI2(2))*(X(2)-X(1))/4.
      SUM2=(SI2(2)+SI2(3))*(X(3)-X(2))/4.
      SUM3=(SI2(3)+SI2(4))*(X(4)-X(3))/4.
      SUM4=(SI2(4)+SI2(5))*(X(5)-X(4))/4.
      EN2=-SUM2
      EN1=-SUM2-SUM1
      EN3=SUM3
      EN4=SUM3+SUM4
      Y(2)=EXP(EN2)
      Y(1)=EXP(EN1)
      Y(4)=EXP(EN3)
      Y(3)=1.0
      Y(5)=EXP(EN4)
      IF(IND-1) 332,323,323
  323 IF(J-1) 324,324,320
  320 IF(J-3) 322,324,322
  322 IF(J-5) 332,324,332
  324 WRITE(6,326)
  326 FORMAT (/57H SLINE  C8  C9  ITERATION  I'ALFA  I'DSDX  I'TOTAL
     *   Y)
      DO 330 I=1,5
  328 FORMAT (I4,F4.2,F4.2,I9,F12.4,F9.5,F9.4,2F8.4)
  330 WRITE(6,328) I,C8,C9,J,SI1(I),SS(I),SI2(I),Y(I),ALFA1(I)
  332 CONTINUE
      DO 334 I=1,5
      VA1(I)=VA1(3)*Y(I)
```

```
      VU1(I)=VA1(I)*TAN(ALFA1(I))
      V1(I)=VA1(I)/COS(ALFA1(I))
      VR1(I)=-VA1(I)*DR(I)/2./CL
      V1(I)=SQRT(V1(I)*V1(I)+VR1(I)*VR1(I))
      T(I)=TTO-V1(I)**2/Q1
      T1IS(I)=TTO-(TTO-T(I))/ETA(I)
      P(I)=PTO*(T1IS(I)/TTO)**EXP1
  334 PRA1(I)=P(I)/PTO
  336 DO 352 I=1,5
      AMS(I)=V1(I)/SQRT(GAM*ERRE*G*T(I))
  352 CONTINUE
  356 RETURN
      END
C
      SUBROUTINE ROTO1  (VU1,VA1,RPM,U,BETA1,HE,TTE,PTE,X2,P1,T1,W1,WU1,
     *X1,RS,ZETAR,ZETAPR,RR,DHEDX,DSDX,S,U2,OMEG,BR1,BR2,BR3,FS1,FS2,
     *ZETA,B6,RS1,RS3,RS5,BETO,STALI,BINC,VR1)
      DIMENSION VU1(5),VA1(5),U(5),BETA1(5),HE(5),TTE(5),PTE(5),
     *X2(5),P1(5),T1(5),W1(5),WU1(5),X1(5),RS(5),ZETAR(5),
     *ZETAPR(5),RR(5),DHEDX(5),DSDX(5),S(5),U2(5),ZETA(5),
     *VR1(5),B6(10),BETO(5),STALI(5),BINC(5)
      COMMON/CSS/CJ,G,Q1
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/IWI/IND,INZ,IWR
      C=2.*32.174*778.16*CP
      OMEG=RPM*3.1416/30.
      DO 520 I=1,5
      U(I)=OMEG*RS(I)/12.
      U2(I)=U(I)*RR(1)/RS(I)
      WU1(I)=VU1(I)-U(I)
      BETA1(I)=ATAN(WU1(I)/VA1(I))
      W1(I)=VA1(I)/COS(BETA1(I))
      W1(I)=SQRT(VR1(I)*VR1(I)+W1(I)*W1(I))
      TTE(I)=T1(I)+W1(I)**2/C+(U2(I)**2-U(I)**2)/C
      PTE(I)=P1(I)*(TTE(I)/T1(I))**EXP1
      HE(I)=TTE(I)*.24
      IF(RS(I)-RS3) 512,514,516
  512 ZETAR(I)=ZETA(I)+(RS(I)-RS1)/(RS3-RS1)*(ZETA(3)-ZETA(1))
      GO TO 518
  514 ZETAR(I)=ZETA(3)
      GO TO 518
  516 ZETAR(I)=ZETA(3)+(RS(I)-RS3)/(RS5-RS3)*(ZETA(5)-ZETA(3))
  518 ZETAPR(I)=ZETAR(I)/2.0
  520 CONTINUE
      DSDX(1)=(S(2)-S(1))/(X2(2)-X2(1))
      DSDX(2)=0.5*(DSDX(1)+(S(3)-S(2))/(X2(3)-X2(2)))
      DSDX(3)=0.5*((S(4)-S(3))/(X2(4)-X2(3))+(S(3)-S(2))/(X2(3)-X2(2)))
      DSDX(5)=(S(5)-S(4))/(X2(5)-X2(4))
      DSDX(4)=0.5*(DSDX(5)+(S(4)-S(3))/(X2(4)-X2(3)))
      DHEDX(1)=(HE(2)-HE(1))/(X2(2)-X2(1))
      DHEDX(2)=.5*(DHEDX(1)+(HE(3)-HE(2))/(X2(3)-X2(2)))
      DHEDX(3)=0.5*((HE(3)-HE(2))/(X2(3)-X2(2))+(HE(4)-HE(3))/
     * (X2(4)-X2(3)))
      DHEDX(5)=(HE(5)-HE(4))/(X2(5)-X2(4))
      DHEDX(4)=0.5*(DHEDX(5)+(HE(4)-HE(3))/(X2(4)-X2(3)))
  522 CONTINUE
      RETURN
      END
C
      SUBROUTINE ROTO2  (BETA2,HE,DHEDX,DSDX1,DSDX2,VA2,WU2,W2,VU2,V2,
     *X2,U,YR,ZETAR,RI1,RI2,RI3,RI4,RI,SR1,SR2,AA,SR,TTE,PTE,T2,P2,PRAT2
     *,T2S,INDS,DBET,RRF,DELR,CL,CK,DR,R,RR1,RR3,RR5,NS,WR2)
      DIMENSION BETA2(5),HE(5),DHEDX(5),DSDX1(5),DSDX2(5),VA2(5),
     *WU2(5),W2(5),VU2(5),V2(5),X2(5),U(5),YR(5),ZETAR(5),
     *RI1(5),RI2(5),RI3(5),RI4(5),RI(5),SR1(5),SR2(5),YOLD(5),
     *AA(5),SR(5),TTE(5),PTE(5),T2(5),P2(5),PRAT2(5),T2S(5),
     *DBET(5),BETAM(5),AMR(5),DBETDX(5),BETA(5),DELR(5),RIS(5),
     *DR(5),R(5),WR2(5)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/CSS/CJ,G,Q1
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/IWI/IND,INZ,IWR
      INDS=0
      INDS1=0
      C=2.*G*CJ
      Q1=C/VA2(3)**2
      DO 274 I=1,5
      IF(R(I)-RR3) 270,271,273
  270 BETA2(I)=BETA2(3)+(R(I)-RR3)/(RR1-RR3)*DBET(1)
      GO TO 274
```

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  271 BETA2(I)=BETA2(3)
      GO TO 274
  273 BETA2(I)=BETA2(3)+(R(I)-RR3)/(RR5-RR3)*DBET(5)
  274 CONTINUE
      DBETDX(1)=(BETA2(2)-BETA2(1))/(X2(2)-X2(1))
      DBETDX(5)=(BETA2(5)-BETA2(4))/(X2(5)-X2(4))
      DO 280 I=2,4
      M=I-1
      N=I+1
  280 DBETDX(I)=.5*((BETA2(N)-BETA2(I))/(X2(N)-X2(I))+(BETA2(I)-BETA2
     *(M))/(X2(I)-X2(M)))
      DO 10 I=1,5
  200 TAN1=-2.*TAN(BETA2(I))
      PROD=TAN1*DBETDX(I)
      SIN1=-2.*SIN(BETA2(I))**2/X2(I)
      RI1(I)=PROD+SIN1+DSDX1(I)
      SR1(I)=-4.*U(3)*COS(BETA2(I))*SIN(BETA2(I))/(VA2(3)*YR(I))
      SR2(I)=2.*U(3)*U(I)*COS(BETA2(I))**2/(VA2(3)**2*YR(I)**2)
      YOLD(1)=YR(I)
      AA(I)=(VA2(3)*YR(I)/COS(BETA2(I)))**2/(C*HE(I))
      RI3(I)=(C*COS(BETA2(I))**2/((VA2(3)*YR(I))**2))*DHEDX(I)
      IF (INDS1-1) 10,250,250
   10 CONTINUE
  281 IF(IND-1) 201,282,282
  282 WRITE(6,121)(RI1(I),I=1,5)
  121 FORMAT(/23H CONSTANT INTEGRAND 1-5, 5F8.5)
      WRITE (6,122)
  122 FORMAT(/60H SLINE  INDS1  GRAD S   INT2   INT3    INT4    INT
     *r VAL)
  201 DO 20 J=1,13
      DO 30 I=1,5
      AA(I)=AA(I)*(YR(I)/YOLD(I))**2
      ANUM=1.-AA(I)
      ADEN=1.-AA(I)/(1.-ZETAR(I))
      AB=ANUM/ADEN
      IF (AB) 130,130,30
  130 INDS=1
      GO TO 150
   30 SR(I)=ALOG(ANUM/ADEN)
      DSDX2(1)=(SR(2)-SR(1))/(X2(2)-X2(1))
      DSDX2(2)=0.5*(DSDX2(1)+(SR(3)-SR(2))/(X2(3)-X2(2)))
      DSDX2(3)=0.5*((SR(3)-SR(2))/(X2(3)-X2(2))+(SR(4)-SR(3))/
     * (X2(4)-X2(3)))
      DSDX2(5)=(SR(5)-SR(4))/(X2(5)-X2(4))
      DSDX2(4)=0.5*(DSDX2(5)+(SR(4)-SR(3))/(X2(4)-X2(3)))
      DO 40 I=1,5
      SR1(1)=SR1(I)*YOLD(I)/YR(I)
      SR2(I)=SR2(I)*(YOLD(I)/YR(I))**2
      RI2(I)=SR1(I)-SR2(I)
      RI3(I)=RI3(I)*(YOLD(I)/YR(I))**2
      IF(NS-1) 31,32,32
   31 RI4(I)=DSDX2(I)-(DSDX1(I)+DSDX2(I))*C1*HE(I)
     * *(COS(BETA2(I))/YR(I))**2
      GO TO 40
   32 RI4(I)=-(DSDX1(1)+DSDX2(I))*C1*HE(I)*(COS(BETA2(I))/YR(I))**2
      RI5(I)=(DSDX1(I)+DSDX2(I))*(SIN(BETA2(I))**2+COS(BETA2(I))**2
     ***((CL**2+(DR(I)/2.0)**2)/CL**2))-COS(BETA2(I))**2*(2.*CK*RRF*
     *DELR(I))/CL**2
      RI4(I)=RI4(I)+RI5(I)
   40 RI(I)=RI1(I)+RI2(I)+RI3(I)+RI4(I)
      SUM1=(RI(1)+RI(2))*(X2(2)-X2(1))/4.
      SUM2=(RI(2)+RI(3))*(X2(3)-X2(2))/4.
      SUM3=(RI(3)+RI(4))*(X2(4)-X2(3))/4.
      SUM4=(RI(4)+RI(5))*(X2(5)-X2(4))/4.
      EN1=-(SUM2-SUM1)
      EN2=-SUM2
      EN4=SUM3
      EN5=SUM3+SUM4
      DO 50 I=1,5
   50 YOLD(I)=YR(I)
      YR(1)=EXP(EN1)
      YR(2)=EXP(EN2)
      YR(3)=1.0
      YR(4)=EXP(EN4)
      YR(5)=EXP(EN5)
      NCOUNT=0
      DO 1001 I=1,5
      IF(YR(I).GT.2.0) YR(I)=2.0
      IF(YR(I).LT.0.2) YR(I)=0.2
 1001 CONTINUE
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      DO 110 I=1,5
      TEST=ABS(YOLD(I)-YR(I))
      IF(TEST-TOL4) 110,110,119
  110 NCOUNT=NCOUNT+1
      IF(NCOUNT-5) 119,140,119
  119 IF(IND-1) 20,120,120
  120 IF(J-3) 80,100,80
   80 IF(J-6) 90,100,90
   90 IF(J-9) 160,100,160
  160 IF(J-12) 20,100,20
  100 DO 60 I=1,5
  123 FORMAT (I4,I7,F10.5,5F8.4)
   60 WRITE (6,123) I,INDS1,DSDX2(I),RI2(I),RI3(I),RI4(I),RI(I),YR(I)
   20 CONTINUE
  140 DO 70 I=1,5
      VA2(I)=YR(I)*VA2(3)
      W2(I)=VA2(I)/COS(BETA2(I))
      WR2(I)=-VA2(I)*DR(I)/2./CL
      W2(I)=SQRT(W2(I)*W2(I)+WR2(I)*WR2(I))
   70 T2(I)=TTE(I)-W2(I)**2/(0.24*C)
      IF(INDS1-1) 251,149,149
  251 INDS1=INDS1+1
      DO 250 I=1,5
      AMR(I)=W2(I)/SQRT(GAM*ERRE*G*T2(I))
  250 CONTINUE
  149 DO 190 I=1,5
      WU2(I)=VA2(I)*TAN(BETA2(I))
      VU2(I)=WU2(I)+U(I)
      T2S(I)=TTE(I)-(TTE(I)-T2(I))/(1.-ZETAR(I))
      P2(I)=PTE(I)*(T2S(I)/TTE(I))**(GAM/(GAM-1.))
      PRAT2(I)=P2(I)/PTE(I)
  190 CONTINUE
  150 RETURN
      END
C
      SUBROUTINE FLOWR(PRAT,ZETAP,X,WI,PTE,PTO,TTE,TTO,AS,ZS,RS,AR,ZR,
     *RR,M,WCHAN,VA,WPER,CODE,WLBM,B,R,TIPC,A)
      DIMENSION PRAT(10),ZETAP(10),X(10),WI(10),PTE(10),TTE(10),
     *VA(10),WPER(10),B(20),A(10),R(10)
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/MAC/IN
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/CSS/CJ,G,Q1
      COMMON/ARA/BA17,BLEX
      COMMON/IWI/IND,INZ,IWR
      IN=20
      C=BLEX
      A(3)=B(1)+B(2)*R(3)+B(3)*R(3)**2+B(4)*R(3)**3+B(5)*R(3)**4
      F1=1./(C+1.)
      F2=1./(3.*C+1.)
      F3=1./(5.*C+1.)
      F4=1./(7.*C+1.)
      F5=1./(9.*C+1.)
      F6=1./(11.*C+1.)
      PRATCR=(2./(GAM+1.))**(GAM/(GAM-1.))
      PHICR=(2./(GAM+1.))**(1./(GAM-1.))*SQRT(2.*GAM/(GAM+1.))
      DO 420 I=1,5
      IF (PRATCR-PRAT(I)) 400,402,402
  400 XE=1.-PRAT(I)**((GAM-1.)/GAM)
      GO TO 404
  402 XE=1.-PRATCR**((GAM-1.)/GAM)
  404 XE2=XE**2
      XE3=XE**3
      XE4=XE**4
      XEINV=1./(XE-1.)
      HNUM=XEINV+F2+XE*F3+XE2*F4+XE3*F5+XE4*F6
      HDEN=XEINV+F1+XE*F2+XE2*F3+XE3*F4+XE4*F5
      HSTAR=HNUM/HDEN
      XI=(HSTAR-1.)/(HSTAR-1.+ZETAP(I))
      IF (PRATCR-PRAT(I)) 406,408,408
  406 PHI=SQRT(2.*GAM/(GAM-1.)*(PRAT(I)**(2./GAM)-PRAT(I)**
     *((GAM+1.)/GAM)))
      GO TO 410
  408 PHI=PHICR
  410 A(I)=B(1)+B(2)*R(I)+B(3)*R(I)**2+B(4)*R(I)**3+B(5)*R(I)**4
      ARAT=A(I)/A(3)
      IF(M-2) 415,412,415
  412 IF(I-5) 415,414,414
  414 ARAT=ARAT+2.*3.1416*R(5)*TIPC/(ZR*AR*RR*(X(5)-X(4)))
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  415 IF(IND-1) 420,416,416
  416 WRITE(6,418) XI,PHI,ARAT
  418 FORMAT (/5H  XH=, F6.4, 6H  PHI=, F7.5, 7H  ARAT=,F6.4)
  420 WI(I)=(PTE(I)/PTO)/SQRT(TTE(I)/TTO)*ARAT*XI*PHI*COSL(I)
      SUM1=(WI(1)+WI(2))*(X(2)-X(1))/2.
      SUM2=(WI(2)+WI(3))*(X(3)-X(2))/2.
      SUM3=(WI(3)+WI(4))*(X(4)-X(3))/2.
      SUM4=(WI(4)+WI(5))*(X(5)-X(4))/2.
      WSUM=SUM1+SUM2+SUM3+SUM4
      IF(M-1) 428,426,428
  426 WREQ=WCHAN/(AS*ZS*RS)
      DIFF=ABS(WREQ-WSUM)
      GO TO 430
  428 WREQ=WCHAN/(AR*ZR*RR)
      DIFF=ABS(WREQ-WSUM)
  430 TAL=TOL1*WREQ
      IF (DIFF-TAL) 432,432,434
  432 VA(3)=VA(3)
      CODE=20.
      GO TO 442
  434 IF(WSUM-WREQ) 436,432,438
  436 CONTINUE
      IF(PRAT(1).LT.PRATCR.AND.PRAT(5).LT.PRATCR) GO TO 470
      VA(3)=VA(3)*(1.00+DIFF/WREQ*1.01)
      GO TO 442
  438 VA(3)=VA(3)*(1.00-DIFF/WREQ*1.01)
  442 WPER(1)=0.
      WPER(2)=SUM1/WSUM
      WPER(3)=(SUM1+SUM2)/WSUM
      WPER(4)=(SUM1+SUM2+SUM3)/WSUM
      WPER(5)=1.0
      IF(IND-1) 450,423,423
  423 WRITE(6,422) (WI(I),I=1,5)
  422 FORMAT(/20H  FLOW INTEGRAND 1-5, F10.5)
      WRITE(6,424) SUM1,SUM2;SUM3,SUM4,WSUM
  424 FORMAT(/15H SUMS 1-4,  WSUM, 5F10.5)
      WRITE (6,440) WSUM,WREQ,VA(3)
  440 FORMAT(35H REF FLOWS,COMPUTED-REQUIRED,AX VAL,2F10.4,F10.2)
      WRITE (6,444) WCHAN,WLBM
  444 FORMAT(/36H REF FLOW RATE CHANNEL-SQUARE INCHES,F8.5,18H FLOW RATE
     *-LBM/SEC,F8.5)
      WRITE (6,446) M
  446 FORMAT (/30H STREAMLINE FLOW FRACTIONS, M=I2)
      WRITE (6,448) X(2),WPER(2),X(3),WPER(3),X(4),WPER(4)
  448 FORMAT(6F10.4)
      GO TO 450
  470 IN=1
  450 RETURN
      END
C
      SUBROUTINE SLINE (RR,X,DWDX,WPER2,WPER1,HE,U,DHEDX,S,DSDX1,
     *ARF,RRF,FC1,FC2,CODE,M,B)
      DIMENSION RR(10),X(10),DWDX(10),WI(10),WPER2(10),WPER1(10),HE(10),
     *DHEDX(10),S(10),DSDX1(10),U(10),B(20)
      COMMON/TOL/TOL1,TOL2,TOL3;TOL4
      COMMON/IWI/IND,INZ,IWR
      N7=0
      SAVE=RR(3)
      CODE=1.
      DO 700 I=1,4
      J=I+1
  700 DWDX(I)=(WPER2(J)-WPER2(I))/(X(J)-X(I))
      N=0
      DO 720 I=2,4
      K=I+1
      J=I-1
      IF (ABS(WPER2(I)-WPER1(I))-TOL2) 716,716,702
  702 IF (WPER2(I)-WPER1(I)) 704,716,708
  704 XN=X(I)+(WPER1(I)-WPER2(I))/DWDX(J)
      IF(M-1) 706,712,706
  706 SL=(HE(K)-HE(I))/(X(K)-X(I))
      DEL=2.*(SL-DHEDX(I))/(X(K)-X(I))
      DHEDX(I)=DHEDX(I)+DEL*(XN-X(I))
      HE(I)=HE(I)+DHEDX(I)*(XN-X(I))
      SL=(S(K)-S(I))/(X(K)-X(I))
      DEL=2.*(SL-DSDX1(I))/(X(K)-X(I))
      DSDX1(I)=DSDX1(I)+DEL*(XN-X(I))
      S(I)=S(I)+DSDX1(I)*(XN-X(I))
      GO TO 712
  708 XN=X(I)-(WPER2(I)-WPER1(I))/DWDX(I)
```

```
      IF (M-1) 710,712,710
  710 SL=(HE(I)-HE(J))/(X(I)-X(J))
      DEL=2.*(DHEDX(I)-SL)/(X(I)-X(J))
      DHEDX(I)=DHEDX(I)+DEL*(XN-X(I))
      HE(I)=HE(I)+DHEDX(I)*(XN-X(I))
      SL=(S(I)-S(J))/(X(I)-X(J))
      DEL=2.*(DSDX1(I)-SL)/(X(I)-X(J))
      DSDX1(I)=DSDX1(I)+DEL*(SN-X(I))
      S(I)=S(I)+DSDX1(I)*(XN-X(I))
  712 RR(I)=XN*SAVE
      GO TO 718
  716 N=N+1
      IF (N-3) 720,730,720
  718 U(I)=U(I)*XN/X(I)
  720 CONTINUE
      DO 722 I=1,5
  722 X(I)=RR(I)/RR(3)
      FC1=RR(3)/SAVE
      FC2=FC1**2
      RRF=RR(3)
      ARF=B(1)+B(2)*RRF+B(3)*RRF**2+B(4)*RRF**3+B(5)*RRF**4
      IF(IND-1) 732,721,721
  721 IF (M-1) 729,732,729
  729 WRITE (6,724)
  724 FORMAT (/47H SLINE  XNEW  HENEW     DHEDX     S-NEW   DSDX1)
      DO 728 I=1,5
  726 FORMAT (I4,F9.4,F9.2,F9.4,F9.6,F9.5)
  728 WRITE (6,726) I,X(I),HE(I),DHEDX(I),S(I),DSDX1(I)
      GO TO 732
  730 CODE=40.
  732 RETURN
      END
C
      SUBROUTINE ALOS1(ZETAS,ZETAPS)
      DIMENSION ZETAS(10),ZETAPS(10)
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG20,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,T,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETAO(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WU2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STALI(10)
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/CSS/CJ,G,Q1
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/ARE/REE
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/ARA/BA17,BLEX
      COMMON/TRS/TRAS
      DO 6001 MACC=1,5,2
      TRA1=90.-ALFA1(MACC)*57.29578
      TRA2=V1(MACC)*.3048
      TRA3=TTO/1.8
      TRA4=RPM*3.14159/30.*RS(MACC)/12.*.3048
      IF(MACC-3) 6002,6003,6004
 6002 CALL TRAU2 (TRA1,90.,TRA2,TRA3,EMME,GAM,SI,TNI,H,D,TRAS,CI,TRA4,
     *0.,TR16,TRA7,TRA8,TRA9,ZETAS(MACC))
      GO TO 6001
 6003 CALL TRAU2 (TRA1,90.,TRA2,TRA3,EMME,GAM,S,TN, H,D,TRAS,C ,TRA4,
     *0.,TR26,TRA7,TRA8,TRA9,ZETAS(MACC))
      GO TO 6001
 6004 CALL TRAU2 (TRA1,90.,TRA2,TRA3,EMME,GAM,SO,TNO,H,D,TRAS,CO,TRA4,
     *0.,TR36,TRA7,TRA8,TRA9,ZETAS(MACC))
 6001 CONTINUE
      IF(ICOZ.LT.5) GO TO 2026
      DO 2027 MACC=1,5,2
      XY=ZETAS(MACC)/(1.-ZETAS(MACC))
      ZETAS(MACC)=(((1.+XY)/(1.+XY*P1(MACC)/PTO)) **EXP2-1.)/
     *((PTO/P1(MACC))**EXP2-1.)
      IF(ICOZ.EQ.8) ZETAS(MACC)=(((1.+XY)/(1.+XY*BESP))**EXP2-1.)/
     *(1./BESP**EXP2-1.)
 2027 CONTINUE
 2026 CONTINUE
      IF(ICON.NE.3) GO TO 31
   30 DO 32 I=1,5,2
   32 ZETAPS(I)=ZETAS(I)
   31 IF(ICON.NE.2) GO TO 33
      IF(ICOR.EQ.4) ZETAPS(1)=TR16
      IF(ICOR.EQ.4) ZETAPS(3)=TR26
```

```
      IF(ICOR.EQ.4) ZETAPS(5)=TR36
   33 CONTINUE
      IF(ICON.NE.1) GO TO 34
      DO 35 I=1,5,2
   35 ZETAPS(I)=.5*ZETAS(I)
   34 CONTINUE
      DO 66 K=1,5
   66 CONTINUE
      RETURN
      END
C
      SUBROUTINE ALOS2(ZETAR,ZETAPR)
      DIMENSION ZETAPS(10),ZETAS(10),ZETAPR(10),ZETAR(10)
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG2O,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,T,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETAO(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WU2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STALI(10)
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/ABA/BA17,BLEX
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/CSS/CJ,G,Q1
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/ARE/REE
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/TR5/TRA5
      IF(ICOR.NE.4) GO TO 6010
      DO 6011 MACC=1,5,2
      TRA1=90.+BETA2(MACC)*57.29578
      TRAX=90.-BETA1(MACC)*57.29578
      GIUD=BETAO(MACC)-BETA1(MACC)
      IF(IINC.EQ.1.AND.GIUD.GE.0.) TRAX=90.-BETAO(MACC)*57.29578
      TRA2=W2(MACC)*.3048
      TRA3=TTE(MACC)/1.8
      TRA4=U2(MACC)*.3048
      IF(MACC-3) 6012,6013,6014
 6012 CALL TRAU2 (TRA1,TRAX,TRA2,TRA3,EMME,GAM,SIR,TNIR,HR,DZ,TRA5,CIR,
     *TRA4,TIPC,TR16,TRA7,TRA8,TRA9,ZETAR(MACC))
      GO TO 6011
 6013 CALL TRAU2 (TRA1,TRAX,TRA2,TRA3,EMME,GAM,SZ, TNR,HR,DZ,TRA5,CR ,
     *TRA4,TIPC,TR26,TRA7,TRA8,YCL ,ZETAR(MACC))
      GO TO 6011
 6014 CALL TRAU2 (TRA1,TRAX,TRA2,TRA3,EMME,GAM,SOR,TNOR,HR,DZ,TRA5,COR,
     *TRA4,TIPC,TR36,TRA7,TRA8,TRA9,ZETAR(MACC))
 6011 CONTINUE
      DH1=CP*TTO*(1.-(P2(3)/PTO)**EXP2)
      PSI=1./(1.-YCL*DH1*G*CJ/U2(3)/WU2(3))
      ZEZE=ZETAR(3)
      DO 6015 MACC=1,5,2
      ZETAR(MACC)=ZETAR(MACC)+(1.-ZEZE)*(1.-PSI*PSI)
 6015 CONTINUE
 6010 CONTINUE
      IF(ICOZ.LT.5) GO TO 2046
      DO 2047 MACC=1,5
      XY=ZETAR(MACC)/(1.-ZETAR(MACC))
      ZETAR(MACC)=(((1.+XY)/( 1.+XY*P2(MACC)/PTE(MACC)))**EXP2-1.)/
     *((PTE(MACC)/P2(MACC))**EXP2-1.)
      IF(ICOZ.EQ.8) ZETAR(MACC)=(((1.+XY)/(1.+XY*BESP))**EXP2-1.)/
     *(1./BESP**EXP2-1.)
 2046 CONTINUE
 2047 CONTINUE
      IF(ICON.NE.3) GO TO 31
   30 DO 32 I=1,5,2
   32 ZETAPR(I)=ZETAR(I)
   31 IF(ICON.NE.2) GO TO 33
      IF(ICOR.EQ.4) ZETAPR(1)=TR16
      IF(ICOR.EQ.4) ZETAPR(3)=TR26
      IF(ICOR.EQ.4) ZETAPR(5)=TR36
   33 CONTINUE
      IF(ICON.NE.1) GO TO 34
      DO 35 I=1,5,2
   35 ZETAPR(I)=.5*ZETAR(I)
```

```
   34 CONTINUE
      ZETAR(2)= ZETAR(1)+(RR(2)-RR1)/(RR3-RR1)*(ZETAR(3)-ZETAR(1))
      ZETAR(4) =ZETAR (3)+(RR(4)-RR3)/(RR5-RR3)*(ZETAR(5)-ZETAR(3))
      ZETAPR(2)=ZETAPR(1)+(RR(2)-RR1)/(RR3-RR1)*(ZETAPR(3)-ZETAPR(1))
      ZETAPR(4)=ZETAPR(3)+(RR(4)-RR3)/(RR5-RR3)*(ZETAPR(5)-ZETAPR(3))
      DO 7001 I=1,5
 7001 CONTINUE
      RETURN
      END
C
      FUNCTION VAVRA(TH,TE,SP)
C     TH=THROAT OPENING
C     TE=TRAILING EDGE THICKNESS
C     SP=BLADE SPACING
      ARG1=TH/SP
      TERM1=ATAN(SQRT(1.-(ARG1**2))/ARG1)
      TERM2=TERM1*180./3.14159
      TERM3=1.-TERM2/90.
      TERM4=(4.*TE/SP)*TERM3
      ARG2=(TH/SP)+TERM4
      VAVRA=ATAN(SQRT(1.-(ARG2**2))/ARG2)
      RETURN
      END
C
C
C
      FUNCTION XPO(ANG1,ANG2)
      COMMON/TRA/XPO1(5,8),XPO2(6,8),ALF1(8),ALFO1(5),ALFO2(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      IF(ANG2-80.) 1,2,3
    1 CONTINUE
      DO 4 I=1,8
      DO 5 J=1,4
    5 Q(J)=C1(J,I)
    4 Y(I)=YC(ANG2,Q,3)
      GO TO 10
    2 CONTINUE
      DO 6 I=1,8
    6 Y(I)=XPO1(5,I)
      GO TO 10
    3 CONTINUE
      DO 7 I=1,8
      DO 8 J=1,3
    8 Q(J)=C2(J,I)
    7 Y(I)=YC(ANG2,Q,2)
   10 CONTINUE
      DO 11 I=1,7
      IF(ANG1.GE.ALF1(I).AND.ANG1.LE.ALF1(I+1)) GO TO 100
      IF(ANG1.LT.ALF1(1)) GO TO 101
      IF(ANG1.GT.ALF1(8)) GO TO 102
   11 CONTINUE
  100 CONTINUE
      XPO=Y(I)+(Y(I+1)-Y(I))/(ALF1(I+1)-ALF1(I))*(ANG1-ALF1(I))
      IF(ANG2.LT.40) XPO=0.09-(0.09-(XPO1(1,I)+XPO1(1,I+1))/2.)*
     *(ANG2-20.)/20.
      RETURN
  101 XPO=Y(1)
      RETURN
  102 XPO=Y(8)
      RETURN
      END
C
      FUNCTION CSIM(V1,TO,EMME,GAM)
      ERRE=848.*9.80665/EMME
      AST=SQRT(2.*GAM/(GAM+1.)*ERRE*TO)
      AMACH=V1/AST
      IF(AMACH.LE.0.8) CSIM=1.
      IF(AMACH.LE.0.8) GO TO 1000
      IF(AMACH.LE.1.1) CSIM=1.-0.22/0.3*(AMACH-0.8)
      IF(AMACH.LT.1.2.AND.AMACH.GT.1.1) CSIM=0.78+0.15/0.1*(AMACH-1.1
      IF(AMACH.GT.1.2) CSIM=0.92+1.5/.2*(AMACH-1.2)
 1000 RETURN
      END
C
      SUBROUTINE CID(ANG1,T,DEL,CSID,PSID,PSIF,HM,DM)
      DIMENSION X(7),Y1(7),Y2(7)
      FF=1.-DEL/T/SIN(ANG1)
      DATA X/15.,20.,25.,30.,45.,60.,90./
      DATA Y1/ 1.06,1.1,1.17,1.225,1.63,2.1,2.45/
      DATA Y2/0.016,0.0315,0.049,0.072,0.156,0.260,0.4 /
```

```
      A=ANG1*180./3.1415
      DO 1 I=1,6
      IF(A.LE.X(1)) Y=1.+0.06*A/15.
      IF(A.GE.X(I).AND.A.LE.X(I+1)) Y=+(Y1(I+1)-Y1(I))/(X(I+1)-X(I))*
     *(A-X(I))+Y1(I)
      IF(A.LE.X(1)) Z=Y2(1)*A/X(1)
      IF(A.GE.X(I).AND.A.LE.X(I+1)) Z= (Y2(I+1)-Y2(I))/(X(I+1)-X(I))*
     *(A-X(I))+Y2(I)
    1 CONTINUE
      IF(A.GT.X(7)) Y=1.
      IF(A.GT.X(7)) Z=1.
      CSID=1.+(Y-1.)*2.*(1.-EF)
      PSID=Z*4.*(1.-EF)*(1.-EF)
      PSIF=0.025/0.09* HM*HM/DM/DM
      RETURN
      END
C
      FUNCTION CSIW(XPO,CSIP,T,ANG1,AH)
      CSIW=XPO*CSIP*T*SIN(ANG1)/AH
      RETURN
      END
C
      FUNCTION CSIR(S,AH,V1,ANG1,UM,XP)
      SL=S/AH
      IF(SL.LE.0.4) XL=XP*0.65/.4*SL
      IF(SL.GT.0.4.AND.SL.LE.0.8) XL=XP*(0.65+0.45/0.4*(SL-.4))
      IF(SL.GT.0.8.AND.SL.LE.1.5) XL=XP*(1.1+0.04/0.7*(SL-0.8))
      IF(SL.GT.1.5) XL=XP*(1.5+0.6/1.7*(SL-1.5))
      ASC=V1*SIN(ANG1)/UM
      XRO=0.025+0.015/0.64*ASC*ASC
      IF(ASC.LT. .2) XRO=.024
      IF(ASC.GT. .95) XRO=.0475
      CSIR=XRO*XL
      RETURN
      END
C
      FUNCTION ALEAK(DELBET,DM,AL,CLE,ALFA1)
      C1=0.82-0.075*DELBET
      ALEAK=C1*(DM+AL)*CLE/DM/AL/COS(ALFA1)
      RETURN
      END
C
C
      SUBROUTINE CHBFT(X,Y,N,A,M,RX,RH,R)
C     DESCRIPTION OF PARAMETERS:
C        X  ARRAY OF ABSCISSAE DIMENSIONED REAL*4 X(N)
C        Y  ARRAY OF ORDINATES DIMENSIONED REAL*4 Y(N)
C        N  NUMBER OF SAMPLE POINTS (INTEGER)
C        A  ARRAY OF THE OUTPUTTED POLYNOMIAL COEFFICIENTS
C           DIMENSIONED AT LEAST A(M+2) (REAL*4)
C        M  ORDER OF DESIRED APPROXIMATING POLYNOMIAL
C        RX WORK ARRAY DIMENSIONED AT LEAST REAL*4 RX(M+2)
C        RH WORK ARRAY DIMENSIONED AT LEAST REAL*4 RH(M+2)
C        R  INTEGER WORK ARRAY DINENSIONED AT LEAST R(M+2)
C
C     NOTE: DIVIDED DIFFERENCES AND NEWTON'S INTERPOLATING FORMULA IS
C              USED FOR COMPUTING THE POLYNOMIAL COEFFICIENTS.
C
      REAL NEXTHI
      INTEGER RI,RJ,R(1)
      DIMENSION X(1),Y(1),A(1),RX(1),RH(1)
      MPLUS1=M+1
      MPLUS2=M+2
      PREVH=0.0
C     DETERMINE INDEX VECTOR FOR INITIAL REFERENCE SET
      R(1)=1
      R(MPLUS2)=N
      D=(N-1)/MPLUS1
      H=D
      DO 1 I=2,MPLUS1
      R(I)=H+1.0
    1 H=H+D
    2 H=-1.0
C     SELECT M+2 REFERENCE PAIRS AND SET ALTERNATIVE DEVIATION VECTOR
      DO 3 I=1,MPLUS2
      RJ=R(I)
      RX(I)=X(RI)
      A(I)=Y(RI)
      H=-H
    3 RH(I)=H
```

```
C     COMPUTE M+1 LEADING DIVIDED DIFFERENCES
      DO 4 J=1,MPLUS1
      I1=MPLUS2
      AI1=A(I1)
      RHI1=RH(I1)
      I=MPLUS1
    5 DENOM=RX(I1)-RX(I-J+1)
      AI=A(I)
      RHI=RH(I)
      A(I1)=(AI1-AI)/DENOM
      RH(I1)=(RHI1-RHI)/DENOM
      I1=I
      AI1=AI
      RHI1=RHI
      I=I-1
      IF(I-J) 4,5,5
    4 CONTINUE
C     EQUATE (M+1) THE DIFFERENCE TO ZERO TO DETERMINE H
      H=-A(MPLUS2)/RH(MPLUS2)
C     WITH H KNOWN, COMBINE THE FUNCTION AND DEVIATION DIFFERENCES
      DO 6 I=1,MPLUS2
    6 A(I)=A(I)+RH(I)*H
C     COMPUTE POLYNOMIAL COEFFICIENTS
      J=M
    7 XJ=RX(J)
      I=J
      AI=A(I)
      JPLUS1=J+1
      DO 8 I1=JPLUS1,MPLUS1
      AI1=A(I1)
      A(I)=AI-XJ*AI1
      AI=AI1
    8 I=I1
      J=J-1
      IF(J-1) 9,7,7
    9 CONTINUE
C     IF THE REFERENCE DEVIATION IS NOT INCREASING MONOTONICALLY
C     THEN EXIT
      HMAX=ABS(H)
      IF(HMAX.GT.PREVH) GO TO 29
      A(MPLUS2) =-HMAX
      RETURN
C     FIND THE INDEX, IMAX, AND VALUE,HIMAX, OF THE LARGEST ABSOLUTE
C     ERROR FOR ALL SAMPLE POINTS
   29 A(MPLUS2)=HMAX
      PREVH=HMAX
      IMAX=R(1)
      HIMAX=H
      J=1
      RJ=R(J)
      DO 110 I=1,N
      IF(I.EQ.RJ) GO TO 11
      XI=X(I)
      HI=A(MPLUS1)
      K=M
   12 HI=HI*XI+A(K)
      K=K-1
      IF(K-1) 112,12,12
  112 HI=Y(I)
      ABSHI=ABS(HI)
      IF(ABSHI.LE.HMAX) GO TO 11
      HMAX=ABSHI
      HIMAX=HI
      IMAX=I
      GO TO 110
   11 IF(J.GE.MPLUS2) GO TO 110
      J=J+1
      RJ=R(J)
  110 CONTINUE
C     IF THE MAXIMUM ERROR OCCURS AT A NONREFERENCE POINT, EXCHANGE THIS
C     POINT WITH THE NEAREST REFERENCE POINT HAVING AN ERROR OF THE
C     SAME SIGN AND REPEAT
      IF(IMAX.EQ.R(1)) RETURN
      DO 14 I=2,MPLUS2
      IF(IMAX.LT.R(I)) GO TO 15
   14 CONTINUE
      I=MPLUS2
   15 NEXTHI=H
      IF((I-I/2*2).NE.0) NEXTHI=-H
      IF(HIMAX*NEXTHI.GE.0) GO TO 115
```

```
      IF(IMAX.GE.R(1)) GO TO 116
      J1=MPLUS2
      J=M
  117 R(J1)=R(J)
      J1=J
      J=J-1
      IF(J-1) 118,117,117
  118 R(1)=IMAX
      GO TO 2
  116 IF(IMAX.LE.R(MPLUS2)) GO TO 120
      J=1
      DO 121 J1=1,MPLUS2
      R(J)=R(J1)
  121 J=J1
      R(MPLUS2)=IMAX
      GO TO 2
  115 R(I)=IMAX
      GO TO 2
  120 R(I-1)=IMAX
      GO TO 2
      END
C
      SUBROUTINE TRAU1
      COMMON/TRA/XPO1(5,8),XPO2(6,8),ALF1(8),ALFO1(5),ALFO2(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
C
      DO 6 I=1,8
      DO 7 J=1,5
    7 Y(J)=XPO1(J,I)
      DO 8 J=1,6
    8 Y1(J)=XPO2(J,I)
      CALL CHBFT(ALFO1,Y,5,Q,3,RX,RY,IR)
      CALL CHBFT(ALFO2,Y1,6,Z,3,RX,RY,IR)
      DO 12 J=1,4
      C1(J,I)=Q(J)
   12 C2(J,I)=Z(J)
    6 CONTINUE
      RETURN
      END
C
      SUBROUTINE TRAU2 (ANG1,ANGO,V1,TO,EMME,GAM,T,DEZ,HM,DM,CSIP,S,UM,
     *CL,RPRO,R2,R3,YCL,RTOT)
      CSIP=1.
      R=XPO(ANG1,ANGO)
      R1=CSIM(V1,TO,EMME,GAM)
      ANGZ=ANG1*3.1415/180.
      CALL CID(ANGZ,T,DEZ,CSID,PSID,PSIF,HM,DM)
      R2=CSIW(R,CSIP,T,ANGZ,HM)
      R3=CSIR(S,HM,V1,ANGZ,UM,CSIP)
      RPRO=R*CSIP*R1*CSID+PSIF+PSID
      IF(CL.LE.0.) YCL=0.
      IF(CL.LE.0.) GO TO 1000
      DEL=3.1416-(ANGO+ANG1)*3.1416/180.
      ALF1=1.5708-ANGZ
      YCL=ALEAK(DEL,DM,HM,CL,ALF1)
 1000 RTOT=RPRO+R2+R3
C
      RETURN
      END
      FUNCTION YC(XBAR,Q,M)
      DIMENSION Q(6)
      YC=0
      IF(XBAR.EQ.0.) YC=Q(1)
      IF(XBAR.EQ.0.) GO TO 10

      M1=M+1
      DO 1 I=1,M1
    1 YC=YC+Q(I)*XBAR**(I-1)
   10 CONTINUE
 1000 RETURN
      END
```

```
&SHORT T=00003 IS ON CR00025 USING 00024 BLKS R=0000

FTN4,L
      PROGRAM SHORT(5)
      DIMENSION INAM(3)
      DIMENSION NAME(3)
C
C
      COMMON/ABA/BA17,BLEX
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/TRS/TRAS
      COMMON/GAS/CP,GAM,EMME,ERRF,EXP1,EXP2,VIS2,VIS3
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/MAC/IN
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/CSS/CJ,G,Q1
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR,VU1(10)
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/VAR5/PRAT1(10),RINCI(10),ALFA11(10),BETA11(10),ZETA1(10),
     *V2(10),ALFA22(10),BETA22(10)
      COMMON/VAR6/PT2(10),TT2(10),PT1(10),DELH(10),ALFA2(10),VU2(10),
     *WR2(10),T2S(10),T2IS(10)
      COMMON/VAR7/TTIS(5),BETAT(5),ETAT(5),ETAI(10),ETAS(10),ETAR(10),
     *RSTAR(10),AKIS(10),PSIR(10)
      COMMON/VAR8/DR1(10),AMW1(10),AMV2(10),BETET(10),PRAT1T(10),AMR2(
     *10),YS(10),X1(10),AREA1(10),ZETAPS(10),WPER1(10),YR(10),X2(10)
      COMMON/VAR9/ZETAR(10),ZETAPR(10),AS(10),AR(10),SI1(10),SI2(10),
     *S1(10),DSDX1(10),WI1(10),HE(10)
      COMMON/VAR10/WU1(10),DHEDX(10),DSDX2(10),RI1(10),RI2(10),
     *RI3(10),RI4(10),RI(10),SR1(10),SR2(10)
      COMMON/VAR11/YOLD(10),AA(10),SR(10),PRAT2(10),WPER2(10),
     *DWDX(10),T1IS(10),PRAT3(10),SS(10),ALFA(10)
      COMMON/VAR12/BETA(10),DELR(10),WPERO(10),ZETAS(10),ZETAR1(20),
     *ZETAR3(20),ZETAR5(20),R1(20),A1(20),T10(20)
      COMMON/VAR13/ST1(20),IRR(20),R2(20),A2(20),RINC(20),DR(10),
     *BETO(10),STALII(10),AREA2(10),VR1(10)
      COMMON/VAR14/WLBM,PRATS,OMEG
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG20,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,T,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETA0(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WO2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STALI(10)
      COMMON/ARE/REE
      COMMON/TRA/XP01(5,8),XP02(6,8),ALF1(8),ALF01(5),ALF02(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      DATA INAM /2HSH,2HOR,2HT /
      DATA NAME /2HPA,2HRT,2H2 /
      CALL TRAU1
      XX=1.25
      BLEX=0.15
      XCL=1.35
C
C
      BESP=(1.+(GAM-1.)/2.*.64)**(-GAM/(GAM-1.))
C
C
C
C
C **********OPERATING CONDITIONS****************
      PTO=38.22
      TTO=626.18
      RPM=12000.
      PR=2.6
C ********************************************
C
C
C ********INITIAL APPROXIMATIONS***************
      AMC=.2247
      AMS=.9
      AMR=.7
      VA1(3)=262.58
      VA2(3)=262.58
```

```
C *********************************************
C
C
C ******SPECIAL INPUT DATA*********************
      TOL1=.01
      TOL2=.01
      TOL3=.01
      TOL4=.01
C
      IND=0
      INZ=0
      IWR=0
      ICOR=4
      IAI=0
C
      IAN=2
      ICL=0
      IINC=1
      ICOZ=6
      ICON=3
C
C *****************************************
C
C *********TURRINE GEOMETRY****************
      A1(1)=.2126
      A1(2)=.22145
      A1(3)=.23035
      A1(4)=.23925
      A1(5)=.24815
      A1(6)=.25705
      A1(7)=.26595
      A1(8)=.27485
      A1(9)=.28375
      A1(10)=.2926
C
      A2(1)=.1912
      A2(2)=.20305
      A2(3)=.21495
      A2(4)=.22685
      A2(5)=.23875
      A2(6)=.25065
      A2(7)=.26255
      A2(8)=.27445
      A2(9)=.28635
      A2(10)=.2983
C
      AL=1.088
      ALI=1.088
      ALO=1.088
C
      C=1.003
      CI=1.003
      CO=1.003
C
      E=2.8065
      EI=2.8065
      EO=2.8065
C
      T=.2252
      TI=.2252
      TO=.2252
C
      TE=.03
      TEI=.03
      TEO=.03
C
      TN=.0186
      TNI=.0186
      TNO=.0186
C
      ALR=1.088
      ALIR=1.088
      ALOR=1.088
C
      CR=1.003
      CIR=1.003
      COR=1.003
C
      ER=2.45
      EIR=2.45
```

```
      EOR=2.45
C
      TR=.2252
      TIR=.2252
      TOR=.2252
C
      TER=.03
      TEIR=.03
      TEOR=.03
C
      TNR=.0186
      TNIR=.0186
      TNOR=.0186
C
      RC(1)=2.764
      RC(5)=3.627
C
      RS(1)=2.764
      RS(5)=3.627
C
      RR(1)=2.693
      RR(5)=3.837
C
      CV=.885
      CK=5.0
      TIPC=.01
      ZS=31.
      ZR=32.
C ************************************
C
C
      RC(2)=SQRT(RC(5)*RC(5)/4.+3./4.*RC(1)*RC(1))
      RC(3)=SQRT(RC(5)*RC(5)/2.+RC(1)*RC(1)/2.)
      RC(4)=SQRT(3./4.*RC(5)*RC(5)+RC(1)*RC(1)/4.)
      RS(2)=SQRT(RS(5)*RS(5)/4.+RS(1)*RS(1)/4.*3.)
      RS(3)=(RS(1)+RS(5))/2.
      RS(4)=SQRT(((RS(5)**2)*.75)+((RS(1)**2)/4.))
      RR(2)=SQRT(RR(5)*RR(5)/4.+3./4.*RR(1)*RR(1))
      RR(3)=(RR(1)+RR(5))/2.
      RR(4)=SQRT(RR(5)*RR(5)*3./4.+RR(1)*RR(1)/4.)
      DO 3300 I=1,10
      A=I
      R1(I)=RS(1)+(A-1.)/9.*(RS(5)-RS(1))
      R2(I)=RR(1)+(A-1.)/9.*(RR(5)-RR(1))
 3300 CONTINUE
      OI=A1(1)
      OO=A1(10)
      OIR=A2(1)
      OOR=A2(10)
      DO 3711 I=1,10
      IF(RS(3).LE.R1(I)) GO TO 3712
 3711 CONTINUE
 3712 CONTINUE
      I=I-1
      O=A1(I)+(A1(I+1)-A1(I))*(RS(3)-R1(I))/(R1(I+1)-R1(I))
      DO 3713 I=1,10
      IF(RR(3).LE.R2(I))  GO TO 3714
 3713 CONTINUE
 3714 CONTINUE
      I=I-1
      OR=A2(I)+(A2(I+1)-A2(I))*(RR(3)-R2(I))/(R2(I+1)-R2(I))
      H=RS(5)-RS(1)
      D=2.*RS(3)
      S=2.*3.1416*RS(3)/ZS
      SI=2.*3.14165 *RS(1)/ZS
      SO=2.*3.1416*RS(5)/ZS
      SZ=2.*3.1416*RR(3)/ZR
      SIR=2.*3.1416*RS(1)/ZR
      SOR=2.*3.1416*RS(5)/ZR
      DZ=2.*RR(3)
      HR=RR(5)-RR(1)
C
C     STATOR OUTLET ANGLES BY VAVRA METHOD
C
      ALFA1(3)=VAVRA(O,TN,S)
      ANG2I   =VAVRA(OI,TNI,SI)
      ANG2O   =VAVRA(OO,TNO,SO)
C
      DALF(1)=ANG2I-ALFA1(3)
      DALF(3)=0.
```

```
      DALF(5)=ANG20-ALFA1(3)
C
C     ROTOR OUTLET ANGLES BY VAVRA METHOD
C
      BETA2(3)=-1.*VAVRA(OR,TNR,SZ)
      BETAI   =-1.*VAVRA(OIR,TNIR,SIR)
      BETAZ   =-1.*VAVRA(OOR,TNOR,SOR)
C
C
      DBET(1)=BETAI-BETA2(3)
      DBET(3)=0.
      DBET(5)=BETAZ-BETA2(3)
      X1(I)=RS(I)/RS(3)
   10 X2(I)=RR(I)/RR(3)
      RROLD2=RR(2)
      RROLD3=RR(3)
      RROLD4=RR(4)
      RSOLD2=RS(2)
      RSOLD3=RS(3)
      RSOLD4=RS(4)
      RS1=RS(1)
      RS3=RS(3)
      RS5=RS(5)
      RR1=RR(1)
      RR3=RR(3)
      RR5=RR(5)
      CALL CHBFT(R1,A1,10,B1,4,T10,ST1,IRR)
      CALL CHBFT(R2,A2,10,B2,4,T10,ST1,IRR)
      ASF=B1(1)+B1(2)*RS(3)+B1(3)*RS(3)**2+B1(4)*RS(3)**3+B1(5)*RS(3)**4
      ARF=B2(1)+B2(2)*RR(3)+B2(3)*RR(3)**2+B2(4)*RR(3)**3+B2(5)*RR(3)**4
      ASF=.2526
      ARF=.2447
      RSF=RS(3)
      ASFO=ASF
      RSFO=RSF
      RRF=RR(3)
      RRFO=RRF
      ARFO=ARF
C     INPUT PRINTING
C
      WRITE(6,671)
  671 FORMAT(1H1,//60X,12HINPUT PRINTS//40X,50H      R1         A1
     *         R2         A2  /)
      DO 72 I=1,10
      WRITE(6,73) R1(I),A1(I),R2(I),A2(I)
   73 FORMAT(40X,F10.3,F10.4,10X,F10.3,F10.4)
   72 CONTINUE
      WRITE(6,74) ZS,ZR,TIPC,CV,CK
   74 FORMAT(/45X,25HNUMBER OF STATOR BLADES =,F8.0/45X,25HNUMBER OF ROT
     *OR  BLADES =,F8.0/45X,25HROTOR TIP CLEARANCE      =,F8.4/45X,25HAXI
     *AL DISTANCE L          =,F8.2/45X,25HCURVATURE FACTOR K       =,F8.2/
     *//55X,16HBLADING GEOMETRY/)
      WRITE(6,75)
   75 FORMAT(//30X,70H        C          E          T              TE     TN
     *     AL          R  /)
      WRITE(6,76)CI,EI,TI,TEI,TNI,ALI,RS(1),C,E,T,TE,TN,AL,RS(3),CO,EO,
     *TO,TEO,TNO,ALO,RS(5)
   76 FORMAT(30X,7F10.4/22X,6HSTATOR,2X,7F10.4/30X,7F10.4/)
   77 FORMAT(30X,7F10.4/22X,6HROTOR ,2X,7F10.4/30X,7F10.4/)
      WRITE(6,77)CIR,EIR,TIR,TEIR,TNIR,ALIR,RR(1),CR,ER,TR,TER,TNR,ALR,
     *RR(3),COR,EOR,TOR,TEOR,TNOR,ALOR,RR(5)
      WRITE(6,78)
   78 FORMAT(/40X,52HALL DIMENSIONS INDICATED IN THIS TABLE ARE IN INCHE
     *S/)
      WRITE(6,79)ICOR,IAI,IAN,ICOZ,IINC,ICL,ICON
   79 FORMAT(////,40X,27HCORRELATION SYSTEM    ICOR =,I5/61X,6HIAI  =,I5/
     *61X,6HIAN  =,I5/61X,6HICOZ =,I5/,61X,6HIINC =,I5/61X,6HICL  =,I5/6
     *1X,6HICON =,I5)
      WRITE(6,81)CP,EMME,GAM,VIS2,VIS3
   81 FORMAT(/20X, 91HGAS PROPERTIES         CP        MOLECULAR MASS
     * GAMM       VISCOSITY (1)     VISCOSITY (2)/38X,10H(BTU/LB F),32X,13
     *H(LBM /SEC FT),4X,13H(LBM /SEC FT)//36X,F9.3,5X,F10.3,9X,F7.3,2E15
     *.3/)
      CALL EXEC(8,NAME)
C
      END
```

```
&PART2 T=00004 IS ON CR00025 USING 00030 BLKS R=0000

FTN4,L
      PROGRAM PART2(5)
      DIMENSION NAME(3)
      DIMENSION NAMR(3)
      COMMON/ABA/BA17,BLEX
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/TR5/TRAS
      COMMON/GAS/CP,GAM,EMME,ERRE,FXP1,EXP2,VIS2,VIS3
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/MAC/IN
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/CSS/CJ,G,Q1
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR,VU1(10)
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/VAR5/PRAT1(10),RINCI(10),ALFA11(10),BETA11(10),ZETA1(10),
     *V2(10),ALFA22(10),BETA22(10)
      COMMON/VAR6/PT2(10),TT2(10),PT1(10),DELH(10),ALFA2(10),VU2(10),
     *WR2(10),T2S(10),T2IS(10)
      COMMON/VAR7/TTIS(5),BETAT(5),ETAT(5),ETAI(10),ETAS(10),ETAR(10),
     *RSTAR(10),AKIS(10),PSIR(10)
      COMMON/VAR8/DR1(10),AMW1(10),AMV2(10),BETET(10),PRAT1T(10),
     *AMR2(10),YS(10),X1(10),AREA1(10),ZETAPS(10),WPER1(10),YR(10),
     *X2(10)
      COMMON/VAR9/ZETAR(10),ZETAPR(10),AS(10),AR(10),SI1(10),SI2(10),
     *S1(10),DSDX1(10),WI1(10),HE(10)
      COMMON/VAR10/WU1(10),DHEDX(10),DSDX2(10),RI1(10),RI2(10),
     *RI3(10),RI4(10),RI(10),SR1(10),SR2(10)
      COMMON/VAR11/YOLD(10),AA(10),SR(10),PRAT2(10),WPER2(10),
     *DWDX(10),T1IS(10),PRAT3(10),SS(10),ALFA(10)
      COMMON/VAR12/BETA(10),DELR(10),WPERO(10),ZETAS(10),ZETAR1(20),
     *ZETAR3(20),ZETAR5(20),R1(20),A1(20),T10(20)
      COMMON/VAR13/ST1(20),IRR(20),R2(20),A2(20),RINC(20),DR(10),
     *BETO(10),STALII(10),AREA2(10),VR1(10)
      COMMON/VAR14/WLBM,PRAT5,OMEG
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG2O,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,I,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETAO(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALTR,ALR,ALOR,
     *P2(10),W02(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STALI(10)
      COMMON/ARE/REE
      COMMON/TRA/XPO1(5,8),XPO2(6,8),ALF1(8),ALFO1(5),ALFO2(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      DATA NAME /2HPA,2HRT,2H2 /

      DATA NAMR/2HPA,2HRT,2H3 /
      DO 67 I=1,5
      U(I)=RPM*3.14159/30./12.*RS(I)
      DR(I)=0.
      DELR(I)=0.
      ZETAS(I)=.10
      ZETAR(I)=.15
      ZETAPS(I)=0.05
      ZETAPR(I)=0.05
      COSL(I)=1.0
      YS(I)=1.0
   67 YR(I)=1.0
      N9=0.
  750 NS=0
      N9=N9+1
 7750 CONTINUE
  100 RS(2)=RSOLD2
      RS(3)=RSOLD3
      DO 530 I=1,5
  530 X1(I)=RS(I)/RS(3)
      ASF=ASFO
      RSF=RSFO
      FS1=1.0
      FS2=1.0
      CALL CHAN (TTO,AMC,PTO,RC,WLBM,WCHAN,WPERO)
      NS=0
```

```
  810 DO 801 K=1,15
      CALL STATR (ALFA1,X1,TTO,PTO,AMS,T1,P1,V1,VA1,ST1,ST2,YS,S1,
     *DSDX1,VU1,PRAT1,T1IS,SS,DALF,RSF,DELR,CV,CK,ZETAPS,RS,RS1,RS3,
     *RS5,ZETAS,DR,ZETA1,AMS1,NS,VR1)
      CALL ALOS1(ZETAS,ZETAPS)
      DO 120 I=1,5
      PTE(I)=PTO
  120 TTE(I)=TTO
      CALL FLOWR(PRAT1,ZETAPS,X1,WI1,PTE,PTO,TTE,TTO,ASF,ZS,RSF,ASF,
     *ZR,RSF,1,WCHAN,VA1,WPER1,CODE,WLBM,B1,RS,TIPC,AREA1)
      IF(IN.EQ.1) AMC=AMC-.01
      IF(IN.EQ.1) GO TO 7750
      IF(CODE-20.) 801,802,801
  801 CONTINUE
  802 CONTINUE
      FC1=1.
      FC2=FC1**2
      ARF=ARFO
      RRF=RROLD3
      RR(2)=RROLD2
      RR(3)=RRF
      RR(4)=RROLD4
      DO 71 I=1,5
      AMS1(I)=V1(I)/SQRT(GAM*ERRE*G*T1(I))
      X2(I)=RR(I)/RR(3)
   71 CONTINUE
      CALL ROTO1 (VU1,VA1,RPM,U,BETA1,HE,TTE,PTE,X2,P1,T1,W1,WU1,X1,
     *RS,ZETAR,ZETAPR,RR,DHEDX,DSDX1,S1,U2,OMEG,BR1,BR2,BR3,FS1,FS2,
     * ZETAR,B6,RS1,RS3,RS5,BETO,STALII,RINCI,VR1)
      CODE=1.
      IMACC=0
  201 DO 200 K=1,14
      CALL ROTO2 (BETA2,HE,DHEDX,DSDX1,DSDX2,VA2,WU2,W2,VU2,V2,X2,U2,
     *YR,ZETAR,RI1,RI2,RI3,RI4,RI,SR1,SR2,AA,SR,TTE,PTE,T2,P2,PRAT2,
     *T2S,INDS,DBET,RRF,DELR,CV,CK,DR,RR,RR1,RR3,RR5,NS,WR2)
      CALL ALOS2(ZETAR,ZETAPR)
      IF (INDS-1) 310,320,310
  320 WRITE (6,36) (AA(I),I=1,5)
      WRITE(6,36) ((AA(I),ZETAR(I),VA2(I)),I=1,5)
   36 FORMAT(35H ENTROPY INDETERMINATE, PRINT AA 1-5,5E12.4/,25X,10HZETAR
     * 1-5,5E12.4/25X,10H VA2    1-5,5E12.4/)
      IND=1
  310 CALL FLOWR(PRAT2,ZETAPR,X2,WI1,PTE,PTO,TTE,TTO,ASF,ZS,RSF,ARF,
     *ZR,RRF,2,WCHAN,VA2,WPER2,CODE,WLBM,B2,RR,TIPC,AREA2)

      IF(IN.EQ.1) AMC=AMC-.01
      IF(IN.EQ.1) GO TO 7750
  200 CONTINUE
  130 CONTINUE
      IMACC=IMACC+1
      IF(IMACC.GE.10) GO TO 220
 4322 FORMAT( /20H  LOOP IN SLINE ROT//5E10.3)
      IF(CODE-40.) 201,220,201
 5000 CONTINUE
  220 DO 221 I=1,5
      DELR(I)=RS(I)-(RC(I)+RR(I))/2.
      DR(I)=RC(I)-RR(I)
  221 COSL(I)=SQRT(CV*CV/(DR(I)**2+CV*CV))
      NS=1
  880 DO 881 K=1,15
      CALL ALOS1(ZETAS,ZETAPS)
      CALL STATR (ALFA1,X1,TTO,PTO,AMS,T1,P1,V1,VA1,ST1,ST2,YS,S1,
     *DSDX1,VU1,PRAT1,T1IS,SS,DALF,RSF,DELR,CV,CK,ZETAPS,RS,RS1,RS3,
     *RS5,ZETAS,DR,ZETA1,AMS1,NS,VR1)
      DO 860 I=1,5
      PTE(I)=PTO
  860 TTE(I)=TTO
      CALL FLOWR(PRAT1,ZETAPS,X1,WI1,PTE,PTO,TTE,TTO,ASF,ZS,RSF,ASF,
     *ZR,RSF,1,WCHAN,VA1,WPER1,CODE,WLBM,B1,RS,TIPC,AREA1)
      IF(IN.EQ.1) AMC=AMC-.01
      IF(IN.EQ.1) GO TO 7750
      IF(CODE-20.) 881,822,881
  881 CONTINUE
  822 CONTINUE
  861 CALL ROTO1 (VU1,VA1,RPM,U,BETA1,HE,TTE,PTE,X2,P1,T1,W1,WU1,X1,
     *RS,ZETAR,ZETAPR,RR,DHEDX,DSDX1,S1,U2,OMEG,BR1,BR2,BR3,FS1,FS2,
     *ZETAR,B6,RS1,RS3,RS5,BETO,STALII,RINC,VR1)
      CODE=1.
  894 DO 896 K=1,10
      CALL ALOS2 (ZETAR,ZETAPR)
```

```
      CALL ROTO2  (BETA2,HE,DHEDX,DSDX1,DSDX2,VA2,WU2,W2,VU2,V2,X2,U2,
     *YR,ZETAR,RI1,RI2,RI3,RI4,RI,SR1,SR2,AA,SF,TTE,PTE,T2,P2,PRAT2,
     *T2S,INDS,DBET,RRF,DELR,CV,CK,DR,RR,RR1,RR3,RR5,NS,WR2)
      IF(INDS-1) 895,320,895
  895 CALL FLOWR(PRAT2,ZETAPR,X2,WT1,PTE,PTO,TTE,TTO,ASF,ZS,RSF,ARF,ZR,
     *RRF,2,WCHAN,VA2,WPER2,CODE,WLBM,B2,RR,TIPC,AREA2)
      IF(IN.EQ.1) AMC=AMC-.01
      IF(IN.EQ.1) GO TO 7750
      IF(CODE-20.) 896,897,896
  896 CONTINUE
  897 CONTINUE
  226 DO 227 I=1,5
  227 PRAT3(I)=PTO/P2(I)
      IND=0
      PRATS=(PRAT3(1)+2.*(PRAT3(2)+PRAT3(3)+PRAT3(4))+PRAT3(5))/8.
      WRITE(1,265) PRATS
  265 FORMAT(1X,'COMPUTED PRESSURE RATIO=',F6.3)
      DIFF=ABS(PR-PRATS)
      TAL=TOL3*PR
      IF(TAL-DIFF) 920,910,910
  910 N11=0
      GO TO 223
  920 CONTINUE
  710 IF(PR-PRATS) 712,712,714
  712 AMC=AMC-DIFF/18.
      GO TO 750
  714 AMC=AMC+DIFF/18.
      GO TO 750
  223 CONTINUE
      CALL EXEC(8,NAMR)
      END
```

```
&PART3 T=00004 IS ON CR00025 USING 00042 BLKS R=0000

FTN4,L
      PROGRAM PART3(S)
      DIMENSION NAME(3)
      DIMENSION NAMR(3)
      COMMON/ABA/BA17,BLEX
      COMMON/CUR/COSL(10)
      COMMON/TOL/TOL1,TOL2,TOL3,TOL4
      COMMON/TRS/TRAS
      COMMON/GAS/CP,GAM,EMME,ERRE,EXP1,EXP2,VIS2,VIS3
      COMMON/COZ/ICOR,ICOZ,IINC,IAI,ICL,IAN,ICON
      COMMON/MAC/IN
      COMMON/IWI/IND,INZ,IWR
      COMMON/AUS/XCL
      COMMON/CSS/CJ,G,Q1
      COMMON/VAR1/RC(10),RSOLD2,RSOLD3,RSOLD4,ASFO,RSFO,RRFO,ARFO,
     *RR(10),RROLD2,RROLD3,RROLD4,CV,CK,VA1(10),DALF(10),DBET(10),
     *ASF,AMS,B1(20)
      COMMON/VAR2/B6(20),ZR,ZS,ARF,B2(20),PR,AMR,VU1(10)
      COMMON/VAR3/PTE(10),RS1,RS3,RS5,T2(10)
      COMMON/VAR4/BR1,BR2,BR3,RR1,RR3,RR5,VA2(10)
      COMMON/VAR5/PRAT1(10),RINCI(10),ALFA11(10),BETA11(10),ZETA1(10),
     *V2(10),ALFA22(10),BETA22(10)
      COMMON/VAR6/PT2(10),TT2(10),PT1(10),DELH(10),ALFA2(10),VU2(10),
     *WR2(10),T2S(10),T2IS(10)
      COMMON/VAR7/TTIS(5),BETAT(5),ETAT(5),ETAI(10),ETAS(10),ETAR(10),
     *RSTAR(10),AKIS(10),PSIR(10)
      COMMON/VAR8/DR1(10),AMW1(10),AMV2(10),BETET(10),PRAT1T(10),
     *AMR2(10),YS(10),X1(10),AREA1(10),ZETAPS(10),WPER1(10),YR(10),
     *X2(10)
      COMMON/VAR9/ZETAR(10),ZETAPR(10),AS(10),AR(10),SI1(10),SI2(10),
     *S1(10),DSDX1(10),WI1(10),HE(10)
      COMMON/VAR10/WU1(10),DHEDX(10),DSDX2(10),RI1(10),RI2(10),
     *RI3(10),RI4(10),RI(10),SR1(10),SR2(10)
      COMMON/VAR11/YOLD(10),AA(10),SR(10),PRAT2(10),WPER2(10),
     *DWDX(10),T1IS(10),PRAT3(10),SS(10),ALFA(10)
      COMMON/VAR12/BETA(10),DELR(10),WPERO(10),ZETAS(10),ZETAR1(20),
     *ZETAR3(20),ZETAR5(20),R1(20),A1(20),T10(20)
      COMMON/VAR13/ST1(20),IRR(20),R2(20),A2(20),RINC(20),DR(10),
     *BETO(10),STALII(10),AREA2(10),VR1(10)
      COMMON/VAR14/WLBM,PRATS,OMEG
      COMMON/AL1/ALFA1(10),V1(10),TTO,RPM,RS(10),SI,TNI,H,D,CI,T1(10),
     *P1(10),TO,TEI,ALI,BESP,XX,ANG20,AMS1(10),S,TN,C,TE,AL,SO,TNO,
     *CO,TEO,U(10),D1I,D1O,D2I,D2O,ANG2I,ALFAX,TI,T,PTO,ALO,AMC
      COMMON/AL2/BETA2(10),BETA1(10),BETAO(10),W2(10),TTE(10),U2(10),
     *SIR,TNIR,HR,DZ,CIR,TIPC,SZ,TNR,CR,SOR,TNOR,COR,ALIR,ALR,ALOR,
     *P2(10),WU2(10),W1(10),TEIR,TER,TEOR,D1IR,D1OR,BETAZ,BETAI,ANM,
     *TIR,TR,TOR,STALI(10)
      COMMON/ARE/REE
      COMMON/TRA/XP01(5,8),XP02(6,8),ALF1(8),ALF01(5),ALF02(6),
     *Y(10),Y1(10),Q(6),RX(30),RY(30),IR(30),Z(6),C1(4,8),C2(4,8)
      DATA NAME /2HPA,2HRT,2H2 /

      DATA NAMR/2HPA,2HRT,2H3 /

  999 FORMAT(1H1)
      WRITE(6,999)
      WRITE(6,401)
  401 FORMAT(///27X,' SET        PAGE      RPM     TOTAL/STATIC      INLET
     *TOTAL   INLET TOTAL')
      WRITE(6,402)
  402 FORMAT(   27X,67HNUMBER  NUMBER            PRESSURE RATIO   PRESSU
     *RE     TEMPERATURE)
  403 FORMAT(72X, 5H(PSI), 7X,8H(DEG. R)/)
      J=1
      IS=1
      WRITE(6,405)J,IS,RPM,PR,PTO,TTO
  405 FORMAT(27X,I3,I8,F11.1,F14.3,F14.3,F15.2/)
      WRITE(6,404)
  404 FORMAT(//57X21H STATOR EXIT SOLUTION///)
      WRITE(6,406)
  406 FORMAT(1X,'STREAM    RADIAL      X=R/RM   RADIAL    BLADE    Y=VA
     */VAM     BLADE         LOSS          ZETA*       FLOW RATE')
      WRITE(6,407)
  407 FORMAT(1X,109H LINE    POSITION            SHIFT   OPENING
     *       EFFICIENCY   COEFFICIENT   CONTINUITY    FRACTION /)
      WRITE(6,411)
  411 FORMAT(12X,4H(IN),13X,4H(IN),5X,4H(IN))
      DO 408 I=1,5
```

```
      PRAT1(I)=1./PRAT1(I)
      ALFA11(I)=ALFA1(I)*57.3
      BETA11(I)=BETA1(I)*57.3
      ALFA2(I)=ATAN(VU2(I)/VA2(I))
      V2(I)=VA2(I)/COS(ALFA2(I))
      V2(I)=SQRT(V2(1)*V2(I)+WR2(I)*WR2(I))
      ALFA22(I)=ALFA2(I)*57.3
      BETA22(I)=BETA2(I)*57.3
      DELH(I)=(U(I)*VU1(I)-U2(I)*VU2(I))/(G*CJ)
      TT2(I)=TTO-DELH(I)/CP
      PT2(I)=P2(I)*(TT2(I)/T2(I))**EXP1
      PT1(I)=P1(I)*(TTO/T1(I))**EXP1
      T2IS(I)=TTO*(P2(I)/PTO)**EXP2
      T2S(I)=TTE(I)*(P2(I)/PTE(I))**EXP2
      TTIS(I)=TTO*(PT2(I)/PTO)**EXP2
      BETAT(I)=PTO/PT2(I)
      ETAT(I)=(TTO-TT2(I))/(TTO-TTIS(I))
      ETAI(I)=(TTO-TT2(I))/(TTO-T2IS(I))
      ETAS(I)=(TTO-T1(I))/(TTO-T1IS(I))
      ETAR(I)=(TTE(I)-T2(I))/(TTE(I)-T2S(I))
      RSTAR(I)=(T1IS(I)-T2IS(I))/(TTO-T2IS(I))
      AKIS(I)=2.*G*CJ*CP*(TTO-T2IS(I))/U(I)**2
      PSIR(I)=SQRT(ETAR(I))
      DR1(I)=RC(I)-RS(I)
      AMW1(I)=W1(I)/SQRT(GAM*ERRE*G*T1(I))
      AMS1(I)=V1(I)/SQRT(GAM*ERRE*G*T1(I))
      AMV2(I)=V2(I)/SQRT(GAM*ERRE*G*T2(I))
      AMR2(I)=W2(I)/SQRT(GAM*ERRE*G*T2(I))
      BETET(I)=PTE(I)/P2(I)
      PRAT1T(I)=PTO/PT1(I)
  408 WRITE(6,409) I,RS(I),X1(I),DR1(I),AREA1(I),YS(I),ETAS(I),ZETA1(I),
     *ZETAPS(I),WPER1(I)
      DELH(10)=0.
      DO 240 I=1,4
      L=I+1
  240 DELH(10)=DELH(10)+.5*(WPER2(L)-WPER2(I))*(DELH(L)+DELH(I))
      HP=DELH(10)*CJ*WLBM/550.
      AMOM=HP*550./OMEG
      THETA=SQRT(TTO/518.4)
      DELTA=PTO/14.7
      HP1=HP/(THETA*DELTA)
      AMOM1=AMOM/DELTA
      RPM1=RPM/THETA
      WLBM1=WLBM*THETA/DELTA
      ETA5=(ETAI(1)+ETAI(5)+2.*(ETAI(2)+ETAI(3)+ETAI(4)))/8.
      BETA6=(BETAT(1)+BETAT(5)+2.*(BETAT(2)+BETAT(3)+BETAT(4)))/8.
      ETA6=(ETAT(1)+ETAT(5)+2.*(ETAT(2)+ETAT(3)+ETAT(4)))/8.
      AKIS5=(AKIS(1)+AKIS(5)+2.*(AKIS(2)+AKIS(3)+AKIS(4)))/8.
      RSTAR5=(RSTAR(1)+RSTAR(5)+2.*(RSTAR(2)+RSTAR(3)+RSTAR(4)))/8.
  409 FORMAT(1X,I4,F12.3,F10.3,F9.4,F9.4,F11.4,F11.4,F14.4,F13.4,F14.4)
      WRITE(6,412)
  412 FORMAT(///22X,23HABSOLUTE VELOCITY (FPS),27X,23HRELATIVE VELOCITY
     *(FPS)//)
  413 FORMAT(1X,6HSTREAM,2X,2(50H  AXIAL       RADIAL    TANGENTIAL    OVER
     *ALL          ),7H WHEEL )
      WRITE(6,413)
      WRITE(6,414)
  414 FORMAT(1X,6H LINE ,   2(50HCOMPONENT   COMPONENT   COMPONENT    VE
     *LOCITY       ),8HVELOCITY//)
      DO 415 I=1,5
  415 WRITE(6,416) I,VA1(I),VR1(I),VU1(1),V1(I),VA1(I),VR1(I),WU1(I),W1(
     *I),U(I)
  416 FORMAT(I5,2X,2(F8.2,3F12.2,6X),F8.2)
      WRITE(6,418)
  418 FORMAT(///7X,113H      MACH NUMBER                    FLOW ANGLE
     *          TEMPERATURE                 PRESSURE                 PRESSURE)
      WRITE(6,419)
  419 FORMAT(   7X,113H                                    (DEG)
     *          (DEG. R)                   (PSI)                      RATIO  /)
      WRITE(6,492)
  492 FORMAT(  7H STREAM)
      WRITE(6,420)
  420 FORMAT(7H  LINE ,2(24H   ABSOLUTE  RELATIVE    ),2(24H     TOTAL
     * STATIC    ),24H   TOT/TOT    TOT/STA   /)
      DO 422 I=1,5
  422 WRITE(6,421)I,AMS1(I),AMW1(I),ALFA11(I),BETA11(I),TTO,T1(I),PT1(I)
     *,P1(I),PRAT1T(I),PRAT1(I)
  421 FORMAT(I4,3X,2F10.2,4X,2F10.2,4X,2F10.2,4X,2F10.3,4X,F11.4,F10.4)
      WRITE(6,999)
      WRITE(6,401)
```

```
      WRITE(6,402)
      WRITE(6,403)
  452 FORMAT(//57X,21H  ROTOR EXIT SOLUTION///)
      IS=2
      WRITE(6,405) J,1S,RPM,PR,PTO,TTO
      WRITE(6,452)
      WRITE(6,406)
      WRITE(6,407)
      DO 423 I=1,5
  423 WRITE(6,409)I,RR(I),X2(I),DR(I),AREA2(I),YR(I),ETAR(I),ZETAR(I),
     *ZETAPR(I),WPER2(I)
      WRITE(6,412)
      WRITE(6,413)
      WRITE(6,414)
      DO 424 I=1,5
  424 WRITE(6,416)I,VA2(I),WR2(I),VU2(I),V2(I),VA2(I),WR2(I),WU2(I),W2(I
     *),U2(I)
      WRITE(6,418)
      WRITE(6,419)
      WRITE(6,492)
      WRITE(6,420)
      DO 425 I=1,5
  425 WRITE(6,421) I,AMV2(I),AMR2(I),ALFA22(I),BETA22(I),TT2(I),T2(I),
     *PT2(I),P2(I), BETAT(I),PRAT3(I)
      WRITE(6,491)
  491 FORMAT(///)
      WRITE(6,426)
  426 FORMAT(7H STREAM, 41H   EQUIVALENT   EQUIVALENT    EQUIV/STATIC)
  427 FORMAT(7H LINE  , 38H   TEMPERATURE   INLET          PRESSURE)
  428 FORMAT(  7X,      38H                 PRESSURE          RATIO)
  429 FORMAT(  7X ,       22H    (DEG. R)       (PSI)
      WRITE(6,427)
      WRITE(6,428)
      WRITE(6,429)
      DO 430 I=1,5
  430 WRITE(6,431)I,TTE(I),PTE(I),BETET(I)
  431 FORMAT(I4,F13.2,F15.3,F11.1)
      WRITE(6,999)
      WRITE(6,401)
      WRITE(6,402)
      WRITE(6,403)
      IS=3
      WRITE(6,405) J,IS,RPM,PR,PTO,TTO
      WRITE(6,441)
  441 FORMAT(//45X,31HOVERALL TURBINE CHARACTERISTICS///)
      WRITE(6,442)
  442 FORMAT(102H  STREAM         PRESSURE RATIO             EFFICIENCY
     *     HEAD          BLADE/JET     THEORETICAL      )
      WRITE(6,443)
  443 FORMAT(102H   LINE      TOT/STA    TOT/TOT    TOT/STA      TOT/TOT
     *   COEFFICIENT   SPEED RATIO DEGREE OF REACTION /)
      DO 444 I=1,5
      BLAJE=1./SQRT(AKIS(I))
  444 WRITE(6,445) I,PRAT3(I),BETAT(I),ETAI(I),ETAT(I),AKIS(I),BLAJE,RST
     *AR(I)
  445 FORMAT(I5,F14.4,F11.4,F11.4,F13.4,F12.4,F15.4,F16.4)
      WRITE(6,446)
  446 FORMAT(///53X,24HMASS AVERAGED QUANTITIES///)
  447 FORMAT(52X,13HHORSE POWER =,F10.2,3X,4H(HP))
  448 FORMAT(52X,13HMOMENT      =,F10.2,3X,7H(FT-LB))
  449 FORMAT(52X,13HFLOW RATE   =,F10.2,3X,8H(LB/SEC)//)
  461 FORMAT(43X,22HREFERRED  RPM         =,F10.2)
  462 FORMAT(43X,22HREFERRED HORSE POWER =,F10.2,3X,4H(HP))
  463 FORMAT(43X,22HREFERRED MOMENT      =,F10.2,3X,7H(FT-LB))
  464 FORMAT(43X,22HREFERRED FLOW RATE   =,F10.2,3X,8H(LB/SEC)//)
  465 FORMAT(40X,25HTOTAL/STATIC EFFICIENCY =,F10.4)
  466 FORMAT(40X,25HTOTAL/TOTAL  EFFICIENCY= , F10.4)
  467 FORMAT(36X,29HTOTAL/STATIC PRESSURE RATIO =,F10.4)
  468 FORMAT(36X,29HTOTAL/TOTAL  PRESSURE RATIO =,F10.4//)
  469 FORMAT(34X,31HHEAD COEFFICIENT               =,F10.4)
  471 FORMAT(34X,31HTHEORETICAL DEGREE OF REACTION=,F10.4)
  472 FORMAT(34X,31HBLADE/JET SPEED RATIO          =,F10.4)
  473 FORMAT(34X,31HMACH NUMBER AT STATION 0       =,F10.4)
      WRITE(6,447) HP
      WRITE(6,448) AMOM
      WRITE(6,449) WLBM
      WRITE(6,461) RPM1
      WRITE(6,462) HP1
      WRITE(6,463) AMOM1
      WRITE(6,464) WLBM1
```

```
      WRITE(6,465) ETA5
      WRITE(6,466) ETA6
      WRITE(6,467) PRAT5
      WRITE(6,468) BETA6
      WRITE(6,469) AKIS5
      BLAJE5=1./SQRT(AKIS5)
      WRITE(6,472) BLAJE5
      WRITE(6,471) RSTAR5
      WRITE(6,473) AMC
      IF(INZ-1) 400,930,930
  930 IF(N11-1) 400,400,400
  400 CONTINUE
      END
```

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